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MARINE MONITORING AT THE CROFTON, B.C. PULPMILL: NOVEMBER 1983 & APRIL 1986

Regional Program Report 87-10

BY

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ABSTRACT

In November 1983 and April 1986, Environmental Protection (EP) sampled the receiving environment in the vicinity of the British Columbia Forest Products (B.C.F.P.) pulp mill at Crofton, B.C.

Although the mill discharges a large quantity of oxygen-demanding wastes (about 51 tonnes of BOD5/day) into Stuart Channel, dissolved oxygen (DO) levels were only slightly lower in the vicinity of the outfall compared to the reference locations. Throughout the area sampled, dissolved oxygen in the upper 20 m of water was usually 65-85% saturated in November 1983 and supersaturated in April 1986. Dissolved oxygen was generally lowest (48% supersaturation) in the 40-50 m layer in 1983, and in the near-bottom layer in 1986 (78% saturation). Midwater DO depressions may indicate trapped effluent (eg. at station 10 at 10 m DO SAT= 32%). Patterns of DO concentrations are consistent since 1979. Colour was detectable at all stations and was elevated in the 0-10 m layer at reference site 8 (1983). No resin acids or PCB's were detected from surface water samples at the outfall in 1983.

The main impact from the B.C.F.P. discharge is on the benthic habitat. About 19 tonnes of 92% volatile suspended solids per day are discharged in the effluent. This has resulted in a fibre mat accumulation in the vicinity of the outfalls (Ellis 1970, Ellis and Jones 1975). Extensive B.C.F.P. core data from 1986 indicated a 5 cm accumulation of fibres as far as 1.8 km NW and SE of the outfall (Smyth 1986c).

Reducing sediments are common near the outfall. Such reducing sediments with high volatile residues (>10%) were detected at stn 6 (1.1 km NW of the outfall) and at stn 2 (<0.4 km SE of the outfall). According to other studies in similar areas (Pearson and Rosenberg 1976) low abundance and diversity of invertebrates in such sediments are to be expected. Low abundance and diversity at this location was confirmed by McGreer, 1983.

A review of mill monitoring data since 1975 indicates that the size of the fibre mat is dynamic and fluctuates between sampling periods. Time series data indicated that the mat may be increasing on the south-eastern portion and at some center-line stations, while volatile residue values declined in the north-western portion and at some of the edge stations.

Sediment cadmium, zinc and copper levels have generally declined in the outfall and near-outfall areas since 1981. Lead and mercury appear to have risen at all stations due to changes in analytical methods.

Unpublished data (Nelson and Brothers 1986, and Goyette 1979) show a decline in zinc levels in whole oysters sampled in 1986 compared to 1979. Future sampling should be undertaken to establish present oyster metal levels at areas previously sampled by Nelson and Goyette (1976) and Ellis et al. (1981).

Additional monitoring efforts should include ether extractable organic chlorine compounds (EOCL), which are known to be generated in the chlorine bleaching stage of Kraft pulpmills. These compounds (which include guaiacols, catechols and dioxins) were linked to a range of physiological and toxic effects in fish and shellfish at effluent dilutions up to 5000:1, off the Swedish Coast.

KEYWORDS: pulpmill, monitoring, water quality, dissolved oxygen, sediment metals, sediment volatile residue, fibre mat, dioxins.

RESUME

En Novembre 1983 et Avril 1986, la Protection de l'Environnement (PE) a échantillonné l'environnement récepteur à proximité de l'usine de pâtes British Columbia Forest Products (B.C.F.P.) à Crofton, C.-B.

Même si l'usine déverse une large quantité d'eaux usées à haute demande d'oxygène (environ 51 tonnes de DBO5/jour) dans le Canal Stuart, les niveaux d'oxygène dissous (OD) étaient seulement un peu plus bas près de l'émissaire en comparaison avec les sites de référence. Partout dans la région échantillonnée, l'oxygène dissous dans les premiers 20 mètres d'eau était généralement 65 à 85% saturée en Novembre 1983 et sursaturée en Avril 1986. L'oxygène dissous était généralement le plus bas (48% sursaturée) dans la couche 40-50 mètres en 1983, et dans la couche près du fond en 1986 (78% saturation). Les dépressions d'oxygène dissous dans les eaux des couches du milieu peuvent indiquer un effluent piégé (e.g. à la station 10 à 10 mètres, la saturation en OD = 32%). Les patrons des concentrations d'oxgène dissous sont consistants depuis 1979. De la couleur fut détectable à toutes les stations et était élevée dans la couche 0 à 10 mètres au site de référence 8 (1983). Aucune acide de résine ou de BPCs ne furent détectés dans les échantillons d'eau à la surface au-dessus de l'émissaire en 1983.

L'impact principal du déversement de B.C.F.P. est sur l'habitat benthique. Approximativement 19 tonnes par jour à 92% en solides suspendus volatils sont déchargées dans l'effluent. Cela a résulté en une accumulation d'un tapis de fibres à proximité des émissaires marins (Ellis 1970, Ellis and Jones 1975). De nombreuses données de carottes de B.C.F.P. en 1986 ont indiqué une accumulation de 5 cm de fibres aussi loin que 1.8 km N.O. et S.E. de l'émissaire (Smyth 1986c).

Des sédiments réducteurs sont communs près de l'émissaire. De tels sédiments réducteurs à haute teneur de résidus volatils (>10%)

furent détectés à la station 6 (1.1 km N.O. de l'émissaire) et à la station 2 (0.4 km S.E. de l'émissaire). Selon d'autres études à des endroits similaires (Pearson et Rosenberg, 1976), on doit s'attendre à une faible abondance et diversité d'invertébrés dans de tels sediments. Une faible abondance et diversité à cet endroit furent aussi confirmées par McGreer en 1983.

Une revue des données d'échantillonnage de l'usine depuis 1975 indique que la dimension du tapis de fibres est dynamique et fluctue entre les périodes d'échantillonnage. Les données en séries de temps ont indiqué que le tapis semble s' accroître dans la portion sud-est et à quelques stations en bordure, tandis que les valeurs de résidu volatil ont diminué dans la portion nord-ouest et à quelques stations au centre.

Les niveaux de cadmium, zinc et cuivre dans les sédiments ont généralement diminué dans les régions à l'émissaire et près de l'émissaire depuis 1981. Les niveaux de plomb et de mercure semblent avoir augmenté à toutes les stations dû aux changements des méthodes analytiques.

Des données non-publiées (Nelson et Brothers 1986, et Goyette 1979) démontrent un déclin dans les niveaux de zinc dans les huîtres entières échantillonnées en 1986 comparé à 1979. Plus d'échantillonnage devrait être entrepris dans le futur afin d'établir les niveaux présents de métal dans les huîtres dans les régions échantillonnées antérieurement par Nelson et Goyette (1976) et Ellis et al. (1981).

Les efforts additionnels de surveillance devraient inclure les composés de chlore organique d' éther extractible, lesquels sont connus comme étant produits dans la phase de blanchiment par le chlore dans les usines de pâtes et papier. Ces composés (incluant gaïacols, catéchols et dioxinnes) ont été reliés à une variation d'effets physiologiques et toxiques dans les poissons, mollusques et crustacés à des dilutions d'effluent jus qui à 5000: 1 dans les eaux côtières de la Suède.

Mots-clefs: usine de pâtes, échantillonnage, qualité de l'eau, oxygène dissous, métaux dans les sédiments, résidu volatil dans les sédiments, tapis de fibres, dioxinnes.

TABLE OF CONTENTS

		Page
ABSTRACT		i
RESUME		iii
TABLE OF CONTENTS		v
	List of Tables	vii
	List of Figures	ix
1	INTRODUCTION	1
1.1	Mill Operations	1
1.2	Receiving Environment	1
2	MATERIALS AND METHODS	5
2.1	Water Sampling	5
2.1.1	Analytical Procedures - Water	5
2.2	Sediment Sampling	9
2.2.1	Analytical Procedures - Sediment	9
3	RESULTS AND DISCUSSION	10
3.1	Water Samples 1983	10
3.1.1	Water Samples 1986	10
3.2	Sediment Samples 1983	12
3.2.1	Sediment Samples 1986	12
3.3	Data Variability: Lab and Field Replicates	17
3.4	Temporal Changes: 1981, 1983 & 1986	19
3.4.1	Water	19
3.4.2	Sediment	19
3.4.3	Biota	28
4	FUTURE MONITORING REQUIREMENTS	30
4.1	Water Quality	30
4.2	Sediment Quality	30
4.3	Biota	31
4.4	Dioxins and Chlorinated Organic Compounds	32
4.4.1	Dioxins	32
4.4.2	Extractable Organic Chlorine Compounds (EOCL)	33
4.4.3	Monitoring Needs	34

TABLE OF CONTENTS(Continued)

		Page
REFERENCES		36
ACKNOWLEDGEMENTS		41
APPENDIX I	CROFTON STUART CHANNEL STATION LOCATIONS 22 NOV 83	42
APPENDIX II	CROFTON STUART CHANNEL STATION LOCATIONS 10 APRIL 86	44
APPENDIX III	CTD PROFILES AT CROFTON - NOVEMBER 22, 1983 a) Station 1 & 2 b) Station 3 & 4 c) Station 5 & 6 d) Station 8 & 10	46
APPENDIX IV	CTD PROFILES AT CROFTON - APRIL 10, 1986 STATION 1 & 9	51
APPENDIX V	CHANGES IN SEDIMENT METAL CONTENT FROM NOVEMBER 1981, NOV 1983, APR 1986	53
APPENDIX VI	LAB PERFORMANCE DATA ON MARINE SEDIMENT STANDARDS	56
APPENDIX VII	OSBOURNE BAY GROUNDFISH TISSUE METAL LEVELS	59
APPENDIX VIII	TREND ANALYSIS ON BCFP CORE DATA: Three Period Running Average on Volatile Function Data	61

LIST OF TABLES

Table		Page
1	EFFLUENT CHARACTERISTICS B.C.F.P. CROFTON MILL FOR 1986	2
2	CROFTON SAMPLING STATIONS AND PARAMETERS SAMPLED 22 NOV 83	6
3	CROFTON SAMPLING STATIONS AND PARAMETERS SAMPLED 10 APR 86	8
4	WATER QUALITY DATA COLLECTED 22 NOV 83 FROM CROFTON	11
5	WATER QUALITY DATA COLLECTED 10 APR 86 FROM STUART CHANNEL	13
6	PHYSICAL DESCRIPTION OF SEDIMENTS COLLECTED 22 NOV 83 FROM STUART CHANNEL	14
7	TRACE METALS, PCB AND SVR COLLECTED 23 NOV 83 FROM STUART CHANNEL	15
8	PHYSICAL DESCRIPTION OF SEDIMENTS COLLECTED 10 APR 86 FROM STUART CHANNEL	16
9	PARAMETERS IN SEDIMENTS COLLECTED 10 APR 86	18
10	MEAN SEDIMENT TRACE METALS AND SVR IN RELATION TO LOCATION OF MAXIMUM VALUES (UG/G DRY WT.)	20

LIST OF TABLES

Table		Page
11	FIELD AND LAB REPLICATED SEDIMENT SAMPLES COLLECTED 10 APR 86	21
12	B.C.F.P. CORE DATA SHOWING SEDIMENT VOLATILE RESIDUE FRACTION 1975-86	24
13	B.C.F.P. CORE DATA SHOWING FIBRE ACCUMULATION (CM), 1975 TO 1986	25

LIST OF FIGURES

Figure		Page
1	SAMPLING LOCATIONS NEAR B.C.F.P. CROFTON - NOV 22, 1983	3
2	SAMPLING LOCATIONS NEAR B.C.F.P. CROFTON - APRIL 10, 1986	7
3	FIBRE DEPOSITION AROUND B.C.F.P. CROFTON OUTFALLS	23
4	B.C.F.P. CORE STATION LOCATIONS 1975-1986	26
5	B.C.F.P. CORE STATIONS LOCATIONS, 1975-1986, INDICATING CHANGES IN VOLATILE FRACTION	27

1 INTRODUCTION

Environment Canada, Conservation and Protection, Environmental Protection (EP) regularly monitors environmental quality at selected industrial and reference sites along the B.C. coastline to detect changes in marine environmental quality. This report presents data collected on 22 Nov 83 and 10 Apr 86 from the Stuart Channel area in the vicinity of the British Columbia Forest Products (B.C.F.P.) kraft pulp mill located near Crofton, B.C. on S.E. Vancouver Island (Figure 1).

1.1 Mill Operations

The B.C.F.P. Crofton mill began operation in 1957 as a kraft mill and is now a combination of kraft and CTMP (chemical thermal mechanical pulp) and newsprint. Its freshwater supply is drawn from the lower Cowichan River about 18 km away. The mill discharges about 189,000 cubic meters of effluent per day through two submarine outfalls with diffusers located at 18 and 28 m (Smyth 1986a). Prior to discharge, fibre-bearing streams are passed through a clarifier. The CTMP effluent also receives biological treatment in aeration basins. In addition the mill has a foreshore discharge which consists of hydraulic de-barker water from the settling ponds. In-plant and pollution abatement facilities were reviewed by McLean and Tanner (1974).

An effluent database for all pulpmills has recently been created by EP (L. Adamache pers. comm.). Table 1 below lists selected parameters of the 1986 effluent data for B.C.F.P. The mill discharged about 18.9 tonnes of suspended solids per day into Stuart Channel. These solids consist largely of pulp fibres which add to the existing fibre mat and degrade benthic conditions in the vicinity of the outfall.

1.2 Receiving Environment

Waldichuk (1964) reviewed the complex dispersion of effluent within the stratified estuarine system of Stuart Channel. He found that

TABLE 1 EFFLUENT CHARACTERISTICS B.C.F.P. CROFTON MILL FOR 1986

DISCHARGE	PRODUCTION	TOTAL SUSPENDED SOLIDS*			VOLATILE *92%
m3/d 354 days	ADT/d	T/d	kg/ADT N=293	Federal Limit kg/ADT	% COMPLIANT (N=293)
188,797	1929	18.9	9.86	8.3	44

BIOLOGICAL OXYGEN DEMAND (5 day)				TOXICITY 96LC50
Tonnes per Day	Kg/ADT	Federal kg/ADT Limit	% COMPLIANT (N=46)	@ 30% EFFLUENT (N=9)
51.86	26.97	30.8	72	11% COMPLIANT

effluent often obtained an equilibrium density (trapping depth) at 3-10 m. Currents at 4-5 m tend to carry the effluent N.W., while 9-10 m currents tend to transport the effluent S.E. Tidal currents would tend to carry the submerged effluent southeastward on the ebb and northwestward on the flood. Generally, solids discharged from the outfall lie in a south-easterly/northwesterly axis due to the tidal flows (Ellis and Jones 1975).

Knapp and Futer (1979) reviewed the fisheries resources of the area. Stuart Channel has commercially and recreationally important quantities of salmonids, groundfish, crustaceans and molluscs. Perhaps the most serious impact of the mill was the loss of productive commercial oyster beds in 1964 (located north and south of the mill). Nelson (1979) noted that several studies have reported the effects of the pulp mill discharge on local oyster populations (Jackson 1962,

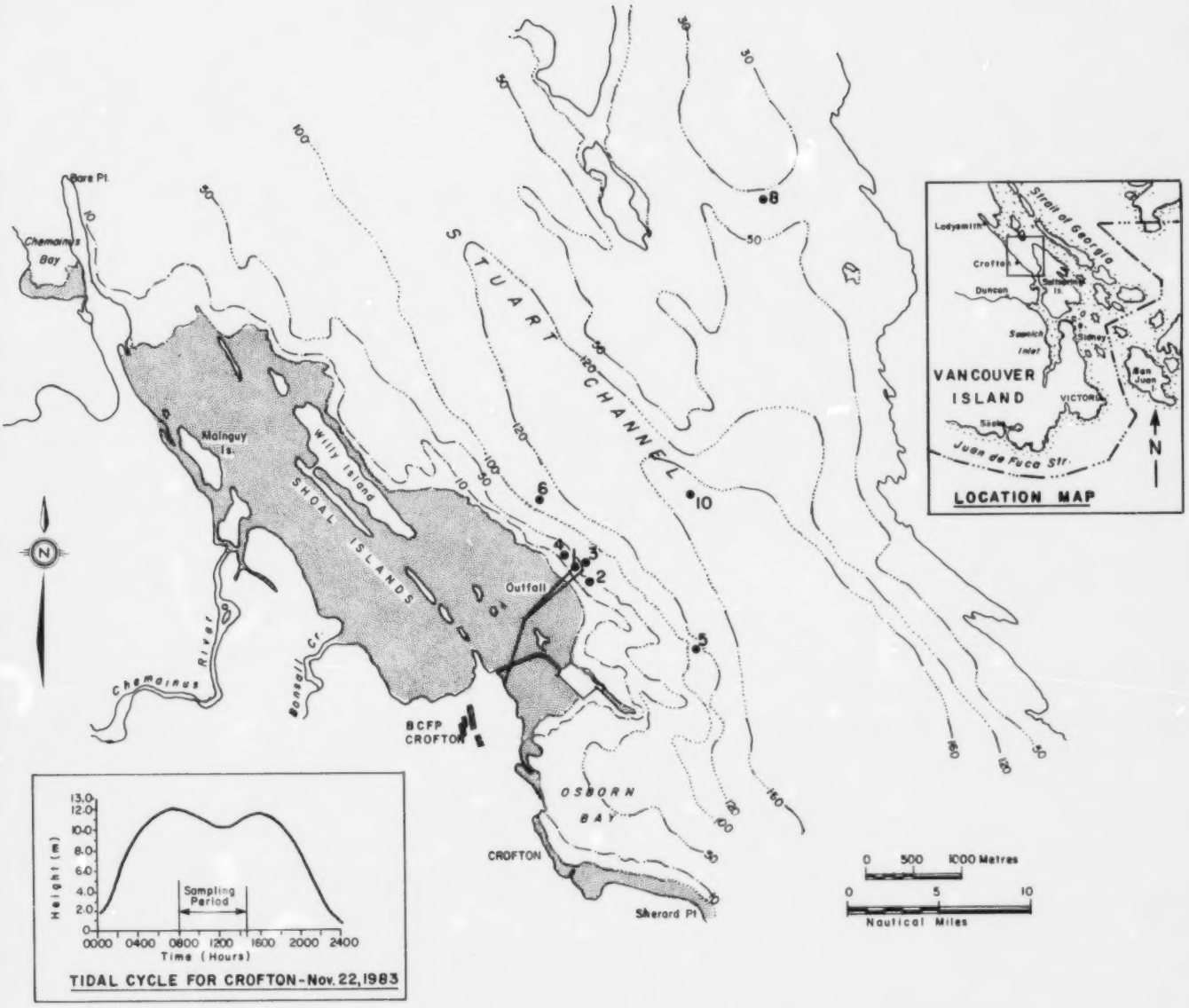

FIGURE 1 SAMPLING LOCATIONS NEAR BCFP CROFTON - November 22, 1983

Porter 1969, Balch 1973, Dobrocky Seatech Ltd. 1977, and Nelson and Goyette 1976).

The Environmental Protection Service has assessed the receiving environment near the mill on previous occasions (Nelson, 1979; Sullivan 1980, 1981, 1982). Nelson (1979) reported widespread zinc contamination of oysters several kilometers north and south of the outfall. Through PISCES IV observations he confirmed the existence of the previously reported fibre bed (Ellis 1970, Ellis and Jones 1975). There were patches of white bacterial or fungal slime [likely Beggiatoa sp.], and a zone at 17 m depth where no epibenthic organisms were observed. Sullivan (1980, 1981, 1982) found lower dissolved oxygen and higher colour values at stations near the outfall in 1979, but not in 1980 or 1981. Sediment cadmium and zinc levels were elevated near the outfall (Cd 1.4 - 3.5 ug/g; Zn 154-278 ug/g). However, levels of Cd, Cu, and Hg were not elevated in shrimp species: Pandalus borealis or P. dispar trawled from Stuart Channel.

McGreer (1984) found a low abundance and diversity of benthic infauna at Crofton to be indicative of a disturbed community. He concluded that the dominance of Paraonis gracilis and Diplodonta orbellus was also indicative of organic enrichment.

The present study will compare previous data with data collected in November 1983 and April 1986.

2 MATERIALS AND METHODS

Surveys were conducted on 22 Nov 83 and 10 Apr 86 from the C.S.S. Vector. Stations were located using ship's LORAN-C and radar. The position of each station is listed in Appendix I (1983) and Appendix II (1986).

In 1983 the sampling effort concentrated on the water column (Table 2, Figure 1), while in 1986 more emphasis was placed on benthic sampling (Table 3, Figure 2). The same field sampling methods were used on both occasions. Trawl samples were not taken due to time constraints. Lab methods are from Swingle and Davidson (1979), unless otherwise stated.

Data and word processing were initially done using "FRAMEWORK II" on an "IBM" - type computer, then reformated on an "AES" machine.

2.1 Water Sampling

Water samples were collected at discrete depths using 1.3 L plastic N.I.O. (National Institute of Oceanography) water bottles. Conductivity, temperature, depth (CTD) profiles were taken using a Plessy Instruments Model 9400 CTD sensor as described by Goyette and Macleod (1984).

2.1.1 Analytical Procedures - Water. Oxygen concentrations were determined in the ship's lab using the azide modification of the Winkler method. The equations of Gameson and Robertson (1955) were used in the calculation of dissolved oxygen saturation. Nutrient samples were immediately frozen (Strickland and Parsons 1971) prior to analysis, then analyzed using an automated colorimeter (Technicon Auto-analyzer II). Tri-stimulus and ADMI colour values were determined spectrophotometrically in the EP West Vancouver lab. Sulfides in water were determined in the lab using a sulfide-ion electrode after preservation on board with zinc acetate and sodium bicarbonate. For non-filterable residue analysis, water was filtered on-board using

TABLE 2 CROFTON SAMPLING STATIONS AND PARAMETERS SAMPLED 22 NOV 83

WATER

Station	CTD[1]	DO[2]	Colour	Sulphides	PCB[3]	Resin Acids	NFR[4]
1	X	X			X	X	
2	X	X	X	X			X
3	X	X	X				X
4	X	X	X	X			X
5	X	X	X				X
6	X	X	X				X
8	X	X	X				
10	X	X	X	X			X

SEDIMENT

Station	SVR[5]	TM[6]	Particle Size	PCB	Resin Acids
1	X	X	X		X
2	X	X	X	X	X
3	X	X	X	X	X
4	X	X	X	X	X
5	X	X	X	X	X
6	X	X	X		X
8	X	X	X	X	X
10	X	X	X		X

1) CTD: Conductivity (Salinity), Temperature, Depth
2) DO: Dissolved Oxygen
3) PCB: Polychlorinated biphenyls
4) NFR: Non-filterable Residue
5) SVR: Sediment Volatile Residue
6) TM: Trace metals

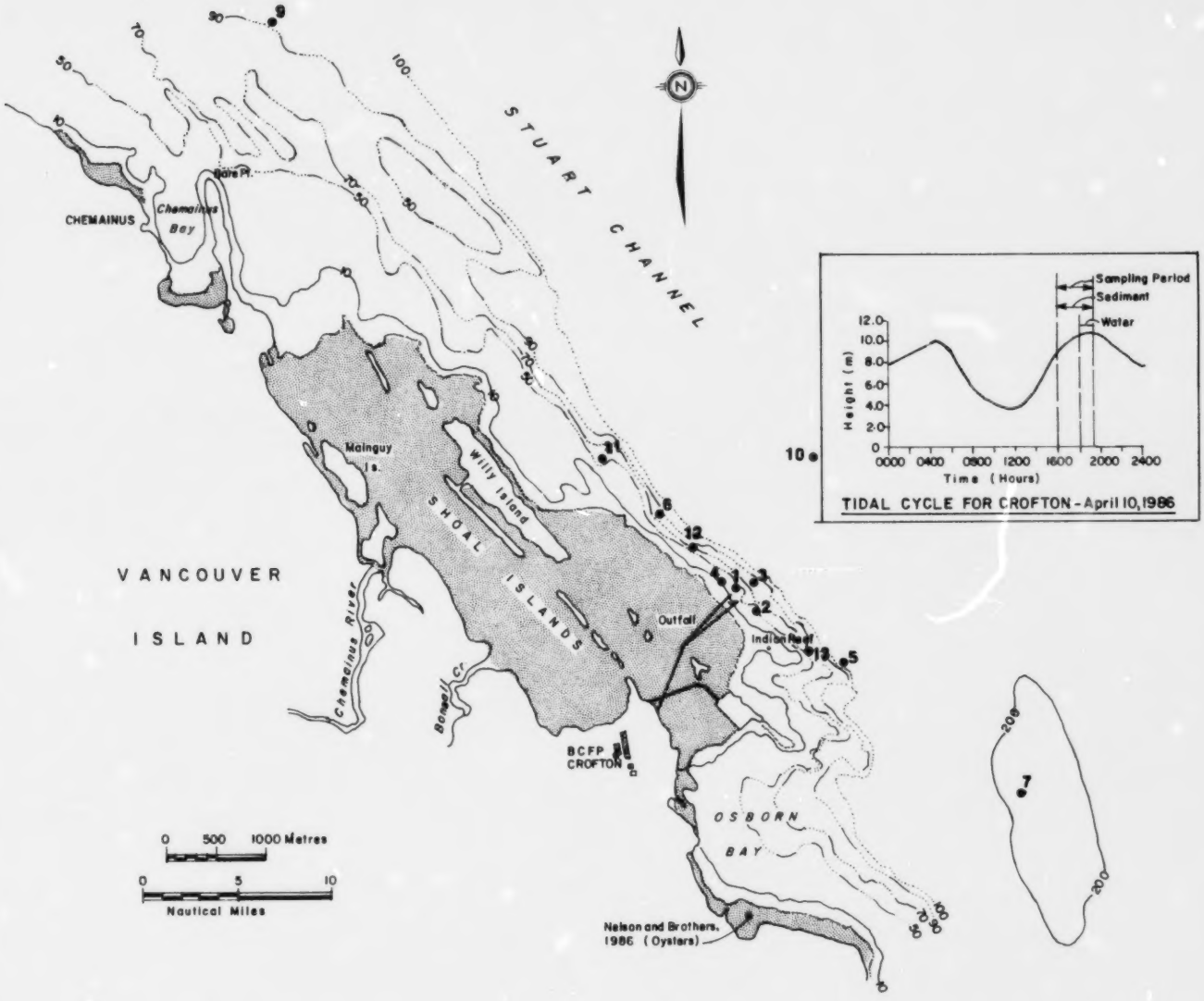

FIGURE 2 SAMPLING LOCATIONS NEAR BCFP CROFTON - April 10, 1986

TABLE 3 CROFTON SAMPLING STATIONS AND PARAMETERS SAMPLED 10 APR 86

	WATER		SEDIMENT		
Station	DO[1]	Colour	SVR[2]	TM[3]	Particle Size
1	X	X	X	X	X
2			X	X	X
3			X	X	X
4			X	X	X
5			X	X	X
6			X	X	X
7			X	X	X
9	X	X	X	X	X
10			X	X	X
11			X	X	X
12			X	X	X
13			X	X	X

1) DO: Dissolved Oxygen
2) SVR: Sediment Volatile Residue
3) TM: Trace Metals and mercury

pre-weighed standard glass fibre filters. The filters were then stored frozen until analysis. Resin acid and PCB water samples were stored in a cooler until they were analysed by gas liquid chromatography.

2.2 Sediment Sampling

Sediment grabs were taken at the stations depicted in Figure 1 using a stainless steel 0.1 m^2 Smith-MacIntyre grab. The top 2 cm surficial sediment layer was collected using a plastic scoop, avoiding the sediment near the sides of the grab. Samples for trace metal analysis, volatile residue, and particle size were placed in paper sediment bags and immediately frozen in plastic bags. Sediments for PCB analysis were collected with a metal spoon, placed in heat-treated glass jars, and stored in a cooler until analysed.

2.2.1 Analytical Procedures - Sediment. Sediments for particle size were freeze-dried and sieved prior to weighing. Median particle size was determined as the size class where the 50th percentile weight was located (Griffiths, 1967). Sediment volatile residue was determined by weight loss upon ignition at 550°C for 1 hour (Swingle and Davidson, 1979).

In 1986 sediment samples were analysed by the EPS/DFO West Vancouver Laboratory for trace metals according to the new procedures recently described by Millward (in prep.). The samples were dried at 60°C and sieved through a (0.15 mm) nylon sieve. They were then digested in a solution of 4.5 ml nitric acid, 1.5 ml hydrochloric acid, and 1 ml distilled water. Samples were digested in a microwave oven for 15 minutes at 720 joules/sec (watts). Trace metals concentrations were determined using a Perkin-Elmer Inductively-Coupled Argon Plasma (ICAP) excitation source coupled to an Optical Emmission Spectrometer. Mercury samples were prepared using a reverse aqua regia digest. Both the micro-wave technique and the reverse aqua regia digest are more efficient at metal extraction than the methods of Swingle and Davidson (1979) used in 1983 (Chris Millward, pers. comm.).

PCB samples were analyzed using electron capture gas liquid chromatography. Resin acids were also determined using liquid chromatography.

3 RESULTS AND DISCUSSION

3.1 Water Samples 1983

November 1983 water quality data is listed in Table 4 while CTD profiles are found in Appendix III. All stations exhibited typical estuarine stratification. Surface salinities ranged from 25.56 ppth to 28.7 ppth. Maximum subsurface salinity (30.13 ppt) was recorded at station 10 (at 170 m). Temperatures showed little spatial variation: ranging from 8.5 to 9.8 C on the surface increasing to a maximum of 10.6 C subsurface.

Surface dissolved oxygen (DO) ranged from 8.0 - 8.3 mg/L (stns 8 and 10) dropping to 7.4 mg/L at stations 1, 4 and 5. This is a dissolved oxygen saturation (DO SAT) range of 78 to 86%. Dissolved oxygen values were generally slightly lower at the stations near the outfall. The 1983 DO maxima are similar to the percent saturation range recorded by Sullivan (1981) for November 1980.

Minimum DO at each station often occurred at 40 - 50 m depth. These low DO values may indicate the influence of "trapped" effluent, but this is not consistently reflected in the non-filterable residue (NFR) data or in the colour data collected in 1983. Similar DO depressions were also noted by Sullivan (1980) in October 1979 at 25 m and 50 m. Sullivan (1982) noted that no mid-depth DO depression was found in November 1981 following a period when the mill was shut-down. Higher surface DO values were also reported for that period.

Maximum colour values levels (ADMI=18) were sampled at outfall station 2 (0 m) in 1983. However, colour was detectable at all stations and was even elevated (ADMI=15) in the 0-10 m layer at reference station 8. This indicates the difficulty of obtaining true "reference sites" within the same oceanographic area.

Resin acids and PCB were undetectable (<0.05 ug/L) in surface water samples from outfall station 1.

3.1.1 Water Samples 1986. In April 1986 two water quality sites were surveyed: one at the outfall (stn 1) and one reference site

TABLE 4 WATER QUALITY DATA COLLECTED 22 NOV 83 FROM CROFTON

Station #	Depth (m)	Salinity (ppt)	Temperature (C)	D.O. (ppm)	% Saturation	Colour (ADMI)	NFR (mg/L)
1	0	26.97	9.27	7.40	78.4	-	-
	20	29.16	10.19	6.00	65.9	-	-
	40	29.59	10.45	4.37	48.5	-	-
2	0	26.90	9.22	7.70	81.5	18	13
	10	27.80	9.58	7.60	81.6	5	14
	20	29.10	10.11	6.05	66.3	8	16
	50	29.90	10.56	4.35	48.4	5	13
	80	30.01	10.45	4.72	52.5	5	17
3	0	28.70	9.36	7.70	82.8	9	16
	10	28.80	9.95	6.45	70.3	14	16
	20	29.20	10.13	5.95	65.2	11	14
	50	29.90	10.50	4.40	48.9	10	17
	65	29.96	10.50	4.68	52.1	8	21
4	0	27.23	9.42	7.40	78.8	-	17
	10	28.29	9.99	7.10	77.2	10	19
	20	29.14	10.11	6.00	65.7	5	21
	40	29.76	10.53	4.30	47.8	5	15
5	0	27.01	9.18	7.40	78.3	13	14
	10	27.96	9.63	7.25	78.5	6	15
	20	28.75	9.95	6.45	70.4	5	18
	50	29.88	10.60	4.50	50.1	5	17
	100	30.06	10.26	5.40	59.8	5	17
	110	30.07	10.24	5.20	57.5	5	14
6	0	26.80	-	7.75	-	5	11
	10	28.13	9.83	6.75	73.0	10	14
	20	29.00	10.04	6.00	65.6	8	22
	50	29.89	10.56	4.35	48.4	5	19
	100	30.02	10.35	4.85	53.8	5	14
	116	-	-	4.95	-	5	14
8	0	27.16	9.18	8.00	84.7	11	-
	10	28.06	9.63	6.65	71.6	15	-
	20	29.24	10.06	6.00	65.7	7	-
	35	29.65	10.44	4.40	50.7	5	-
10	0	25.56	8.57	8.30	85.7	5	13
	10	27.64	9.51	3.00	32.1	5	14
	20	29.03	10.10	5.95	65.2	6	12
	50	29.88	10.51	4.90	54.5	8	12
	100	30.02	10.33	5.05	56.0	5	12
	150	30.11	10.17	-	-	-	-
	170	30.13	10.17	5.20	57.5	5	13

(stn. 9). Station 8 was not used as a reference site because relatively high colour values (ADMI=15) were detected there in 1983. CTD profiles (Appendix IV) show that temperature decreased with depth, while salinity and density increased with depth, as expected. Similar DO SAT profiles were obtained at the outfall and the reference site (Table 5). The top 15 m water layer was supersaturated (101-152%), while the near-bottom layer had the least DO (73-78%). A similar pattern of DO SAT was reported for June 1980 by Sullivan (1981).

Colour was highest at the outfall station on the surface (ADMI=15), and close to detection limits (ADMI=5) elsewhere.

3.2 Sediment Samples 1983

Table 6 shows sediment characteristics of sediments collected in 1983. Median sediment size ranged from granules (stn 10) to very fine sand (stn 8). Surprisingly, deeper stations had coarser sediments. Stations 1 and 4 near the outfall had very high sediment volatile residues (SVR > 20%). These high SVR values and the reducing sediments collected near the outfall are consistent with the documented fibre mat in this area.

Sediment metal levels determined by ICAP are listed in Table 7. Stations are grouped according to proximity to the outfall:

- outfall stations (1,2,3,4)
- near-outfall stations (5,6)
- and reference stations (8,10).

Outfall stations (1, 2, 3, 4) had elevated levels of cadmium, chromium, copper, zinc and sediment volatile residue compared to reference areas (stations 8 and 10). Near-outfall stations had intermediate levels of these parameters. PCB's were also elevated (stns 3,4,5: 0.32 - 0.75 ppm) compared to station 8 (0.05 ppm). Resin acids were undetectable (<2.0 ppm) at all stations.

3.2.1 Sediment Samples 1986. Stations 11, 12, 13 were added in 1986 to better define the extent of the fibre mat previously described and sampled in 1983.

Table 8 lists sediment particle size data collected in 1986.

TABLE 5 WATER QUALITY DATA COLLECTED 10 APR 86 FROM STUART CHANNEL

Station	Depth (m)	Salinity (ppt)	Temperature (C)	D.O. (ppm)	D.O.% Saturation	Colour (ADMI)
OUTFALL STATION 1						
	0	28.6	9.4	13.2	141.7	15
	2	28.6	9.4	13.2	141.8	8
	5	28.7	9.3	11.9	127.6	6
	10	29.1	8.6	9.8	103.7	5
	15	29.1	8.5	9.6	101.4	5
	20	29.3	8.2	8.8	92.4	5
	50	29.9	7.7	7.5	78.0	5
REFERENCE STATION 9						
	0	28.8	9.2	14.2	152.1	7
	2	28.8	9.0	14.2	151.3	7
	5	28.8	8.7	13.4	141.7	6
	10	29.0	8.3	11.3	118.2	6
	15	29.3	8.2	9.7	101.3	5
	20	29.4	8.1	9.4	98.4	5
	50	29.9	7.7	7.6	79.1	5
	90	29.9	7.5	7.0	72.5	5

TABLE 6 PHYSICAL DESCRIPTION OF SEDIMENTS COLLECTED 22 NOV 83 FROM STUART CHANNEL

STATION #	DEPTH (m)	MEDIAN PARTICLE SIZE	SILT & CLAY %	SVR %
1	43	fine sand	21.7	24.1
2	79	medium sand	17.1	14.2
3	73	fine sand	17.7	13.3
4	45	fine sand	16.2	21.8
5	127	granules	5.8	12.1
6	117	very coarse sand	16.1	11.7
8	41	very fine sand	41.7	4.2
10	174	granules	9.5	10.4
		MAX	41.7	24.1
		MIN	5.8	4.2
		MEAN	18.2	14.0
		STD	10.72	6.35
		CV(%)*	59	45

VISUAL DESCRIPTION

Station #

1 - highly reducing, black sediments; wood debris; white amphipods
2 - dark grey/black/green with light brown overlying layer
3 - reducing black/grey/green mud with thin brown layer
4 - fibres, grey/green colour; fly ash; shell fragments; small wood chips mixed in fine clay
5 - grey/green soft clay; worms
6 - dark sediment with dark grey clay; thin, light brown overlaying layer
8 - grey/brown, non-reducing
10 - grey/brown, slightly reducing below; heart urchins

* CV(%) = Coefficient of Variation = $\frac{\text{Standard Deviation}}{\text{Mean}} \times 100$

TABLE 7 TRACE METALS, PCB AND SVR COLLECTED 23 NOV 83 FROM STUART CHANNEL

Station #	Depth (m)	Al (%)	Cd	Cr	Cu	Fe (%)	Hg	Mg (%)	Mn	Mo	Ni	Pb	Sn	Zn	PCB's	SVR (%)	Reducing (R)
							METALS (ug/g DRY WT.)										
OUTFALL STATIONS																	
1	43	1.67	4.20	80.4	77.6	1.85	-	.85	343	29.8	34	14	<2	151	-	24.1	R
2	79	2.50	3.10	54.7	76.5	2.71	-	1.10	338	9.0	32	14	<2	176	.09	14.2	R
3	73	2.35	2.80	50.8	64.8	2.49	-	1.05	340	6.1	26	11	<2	169	.39	13.3	R
4	45	2.06	3.10	64.1	80.5	2.13	-	.95	367	9.3	31	11	<2	195	.75	21.8	R
MAX	79	2.50	4.20	80.4	80.5	2.71	-	1.10	367	29.8	34	14	<2	195	.75	24.1	
MEAN	60	2.15	3.30	62.5	74.9	2.30	-	.99	347	13.6	30.8	12.5	<2	173	.41	18.4	
STD	18.65	.37	.62	13.17	6.91	.38	-	.11	13.49	10.93	3.40	1.73	—	18	.33	5.41	
CV(%)	31	17	19	21	9	17	-	11	4	81	11	14	—	11	81	29	
NEAR-OUT FALL STATIONS																	
5	127	2.47	1.20	48.6	57	2.79	-	1.17	353	1.90	29	18	2	132	.32	12.1	
6	117	2.60	1.70	52.2	70.4	2.98	-	1.20	338	.80	32	15	<2	141	-	11.7	
MAX	127	2.60	1.70	52.2	70.4	2.98	-	1.20	353	1.90	32	18	2	141	.32	12.1	
MEAN	122	2.54	1.45	50.4	63.7	2.89	-	1.19	346	1.35	30.5	17	2	137	.32	11.9	
STD	7.07	.09	.35	2.55	9.48	.13	-	.02	10.61	.78	2.12	2.12	—	6.36	—	.28	
CV(%)	6	4	21	5	13	5	-	2	3	41	7	12	—	5	—	2	
REFERENCE STATIONS																	
8	41	2.24	.70	38.6	43.1	2.60	-	.94	241	.80	24	9	3	94	.05	4.2	
10	174	2.58	.70	48.3	48.2	3.05	-	1.25	344	.80	30	17	<2	115	-	10.4	R
MAX	174	2.58	.70	48.3	48.2	3.05	-	1.25	344	.80	30	17	3	115	.05	10.4	
MEAN	108	2.41	.70	43.5	45.7	2.83	-	1.09	293	.80	27	13	3	105	.05	7.3	
STD	94.05	.24	0	6.86	3.61	.32	-	.22	72.83	0	4.24	5.66	—	14.64	—	4.42	
CV(%)	87	10	0	16	8	11	-	20	25	0	16	44	—	14	—	61	

* FROM TABLE 6 DESCRIPTION

TABLE 8 PHYSICAL DESCRIPTION OF SEDIMENTS COLLECTED 10 APR 86 FROM STUART CHANNEL

STATION #	DEPTH (m)	MEDIAN PARTICLE SIZE	SILT & CLAY %	SVR %
1	66	fine sand	23.9	19.8
2	65	v. fine sand	25.0	14.4
3	101	v. fine sand	34.3	11.6
4	43	fine sand	20.2	31.3
5	125	v. fine sand	41.4	12.5
6	93	v. fine sand	33.7	13.8
7	220	v. fine sand	39.7	9.6
9.1	98	v. fine sand	41.3	11.9
9.2	98	fine sand	29.1	11.7
9.3	98	v. fine sand	36.9	11.7
9 MEAN			35.8	11.8
10	225	v. fine sand	41.7	9.6
11	63	fine sand	14.2	5.4
12	140	fine sand	30.2	14.1
13	82	fine sand	19.4	9.6
		MAX	41.7	31.3
		MIN	14.2	5.4
		MEAN	31.1	13.3
		STD	8.88	5.88
		CV(%)	29	44

VISUAL DESCRIPTION

Station #

1 - fibres, coarse reducing green-black sediment with thin brown surface silt layer
2 - coarse reducing grey-green-black mud, eel grass frond
3 - fibres, coarse reducing grey-black-green mud
4 - thick fibre mat, some wood slivers, Solenmya reidii, Capitella sp.
5 - grey-green silt, not reducing until 10 cm, amphipods, 3 heart urchins (Brisaster sp.)
6 - thin brown layer of silt on black reducing mud, tube-dwelling errant polychaetes
7 - grey-green silt, non-reducing until 10 cm, 8 heart urchins, amphipods
9 - grey-green mud with thin top layer of brown silt, not reducing until 10 cm, 1 heart urchin, sea cucumbers (Molpadia sp.)
10 - 2 cm of grey-brown mud on black reducing sediments, Molpadia, old grass blades
11 - not reducing brown coarse mud, with many polychaetes and amphipods
12 - fewer fibres than station 4, reducing green on black mud
13 - grey-green mud silt, not reducing until 10 cm, tree branch

Median sediment size ranged from fine sand to very fine sand, with finer sediments being collected from deeper stations. As in 1983, stations 1 and 4 had very high SVR values (20 - 30%) coupled with reducing sediments. Reducing sediment was collected at station 6 (1.1 km NW), and at stn 2 (< 0.4 km SE), perhaps suggesting a greater tendency for suspended solids from the mill to be carried further NW than SE. Reference station 10 also had high SVR (>10%), coupled with reducing sediments, in contrast to stations 7 & 9 which had high SVR but non-reducing sediments. Because 1983 colour data indicated the presence of effluent at station 8, it is possible that some volatile suspended matter (fibres) from the mill could be carried to, and deposited in the vicinity of station 10.

Table 9 lists the sediment ICAP metal data for 1986. As in 1983, many of the maxima were found at stations near the outfall. Stations were grouped according to proximity to the outfall:

- outfall stations (1, 2, 3, 4)
- near-outfall stations (5, 6, 11, 12)
- reference stations (7, 9, 10).

Several patterns of metal concentration are evident (Table 10). Sediment volatile residue, cadmium, tin, and zinc all increased with proximity to the outfall. Concentrations of aluminum, iron, mercury and lead, all increased with distance away from the outfall. Chromium, copper, manganese and nickel had the highest concentration in the near-outfall zone.

3.3 Data Variability: Lab and Field Replicates

Field replicated samples were generally more variable than lab replicates (Table 11), reflecting sediment heterogeneity and the need for field replication of samples. However, when elemental concentrations are near their analytical detection limit, higher lab variability can result (e.g. Molybdenum). A coefficient of variation (CV) of 109% was obtained in five lab replications of one field sample (0.8 to 9.10 ug/g dry wt.). Similarly a lab replicated sample of tin

TABLE 9 PARAMETERS IN SEDIMENTS COLLECTED 10 APR 86

METALS (ug/g)

Station #	Depth (m)	Al (%)	Cd	Cr	Cu	Fe (%)	Hg	Mg (%)	Mn	Mo	Ni	Pb	Sn	Zn	PCB'S	SVR (%)	Reducing (R)
OUTFALL STATIONS																	
1	66	2.40	2	45.40	53.80	2.63	.21	1.06	366	16.9	25	30	12	158	-	19.80	R
2	65	2.25	.90	33.30	29.90	2.50	.14	.97	336	15.5	19	21	23	107	-	14.40	R
3	101	2.70	1	42.40	43.30	2.86	.20	1.13	359	12.1	26	28	18	111	-	11.60	R
4 mean	43	1.72	1.30	34.70	45.20	2.18	.16	.89	340	19.9	24	17	4.4	103.4	-	31.30	R
MAX	101	2.70	2	45.40	53.80	2.86	.21	1.13	366	19.9	26	30	23	158	-	31.30	
MEAN	**68.75**	**2.27**	**1.30**	**38.95**	**43.05**	**2.54**	**.18**	**1.01**	**350**	**16.10**	**23.50**	**24**	**14.35**	**119.85**	-	**9.28**	
STD	23.98	.41	.50	5.87	9.89	.28	.03	.10	14.52	3.24	3.11	6.06	8.01	25.62	-	8.71	
CV %	35	18	38	15	23	11	19	10	4	20	13	25	56	21	-	45	
NEAR-OUTFALL STATIONS																	
5	125	2.75	.30	31.80	35.30	3.09	.23	1.21	252	17.7	18	38	9	79.8	-	2.50	
6	93	2.92	1.20	48.60	61.50	3.19	.19	1.29	387	14.8	26	36	17	130	-	3.80	R
MAX	125	2.92	1.20	48.60	61.50	3.19	.23	1.29	387	17.7	26	38	17	130	-	3.80	
MEAN	**109**	**2.84**	**.75**	**40.20**	**48.40**	**3.14**	**.21**	**1.25**	**19.50**	**16.25**	**22**	**37**	**13**	**104.90**	-	**3.15**	
STD	22.63	.12	.64	11.88	18.53	.07	.03	.06	95.46	2.05	5.66	1.41	5.66	35.50	-	.92	
CV %	21	4	85	30	38	2	15	5	30	13	26	4	44	34	-	7	
11	63	2.47	.30	41.10	46.10	2.76	.10	1.04	467	5.3	22	25	16	86.9	-	5.43	
12	140	2.90	.80	51.10	56.70	3.16	.32	1.31	385	13.8	30	32	11	125	-	4.10	R
13 mean	82	2.50	1.10	41.60	42.90	2.76	.11	1.02	372	3	25	22	16.20	104	-	9.64	
MAX	140	2.90	1.10	51.10	56.70	3.16	.32	1.31	467	13.8	30	32	16.20	125	-	14.10	
MEAN	**86.71**	**2.62**	**.73**	**44.60**	**48.57**	**2.89**	**.18**	**1.12**	**408**	**7.37**	**25.67**	**26.33**	**14.40**	**105.30**	-	**9.72**	
STD	43.80	.24	.40	5.63	7.22	.23	.12	.16	51.51	5.69	4.04	5.13	2.95	19.08	-	4.34	
CV %	51	9	55	13	15	8	69	14	13	77	16	19	20	18	-	45	
REFERENCE STATIONS																	
7	220	3.01	.30	20.70	18.20	3.49	.26	1.25	201	26.8	14	37	2	47.5	-	9.62	
9	98	3.01	.83	48.50	53.90	3.27	.17	1.29	359	10.0	27	37	8	113.5	-	11.80	
10	225	2.86	.30	36.50	35	3.30	.18	1.24	304	14.20	22	35	7	82.7	-	9.57	R
MAX	225	3.01	.83	48.50	53.90	3.49	.26	1.29	359	26.8	27	37	8	113.5	-	11.80	
MEAN	**181**	**2.96**	**.48**	**35.23**	**35.70**	**3.35**	**.20**	**1.26**	**288**	**17**	**21**	**36.33**	**5.67**	**81.23**	-	**10.33**	
STD	71.92	.09	.31	13.94	17.86	.12	.05	.03	80.21	8.74	6.56	1.15	3.21	33.02	-	1.27	
CV %	40	3	64	40	50	4	23	2	28	51	31	3	57	41	-	12	

* FROM TABLE 8 DESCRIPTION

(Sn) from STN 4 (mean = 4.4 ug/g) had a CV of 65%. However, when concentration of Sn in sediment increased (STN 13 = 16.5), then CV for tin decreased to 9%.

Sediment volatile residue showed very little field variation (1%), consequently one grab sample at each station is adequate to characterize sediment SVR.

3.4 Temporal Changes: 1981, 1983 & 1986

3.4.1 Water. As noted in the previous sections on water quality, similar patterns of dissolved oxygen values have been obtained from previous surveys since 1979 in Stuart Channel. No improvement or deterioration can be noted in water quality given the snap-shot nature of the water sampling (day-to-day variation caused by wind induced aeration could exceed year-to-year changes). To obtain trends between years an extensive database which included wind/wave information and effluent-loading data would be necessary, if water quality was identifed as a problem. Present DO measurements are meant to serve an environmental audit function.

3.4.2 Sediment. Comparisons of sediment quality are restricted to 1981, 1983 and 1986, when sediment samples were taken from the vicinity of the outfall.

The main impact from the B.C.F.P. pulpmill is on the benthic habitat. Effluent data indicate that about 19 tonnes of suspended solids (>90% volatile) per day are discharged in the effluent. A fibre mat accumulation and reducing sediments in the vicinity of the outfalls has resulted (Figure 3, Ellis 1970, Ellis and Jones 1975, Hinks 1980). Such reducing sediments are usually associated with generally low abundance and diversity of invertebrates in sediments, as described by Pearson and Rosenberg (1976) and McGreer, 1984. Reducing sediments with high sediment volatile residues (>10%) were detected at station 6 (1.1 km N.W. of the outfall) and at station 2 (<0.4 km S.E.) of the outfall in 1986.

Extensive mill core data (Smyth 1986c) indicated a 5 cm accumulation of fibres as far as 1.8 km N.W. and S.E. of the outfall

TABLE 10 MEAN SEDIMENT TRACE METALS AND SVR IN RELATION TO LOCATION OF MAXIMUM VALUES (UG/G DRY WT.)

1986 AREA	HIGHEST AT OUTFALL AREA (reference minimum)				HIGHEST AT NEAR-OUTFALL AREA (reference minimum)				HIGHEST AT REFERENCE AREA (outfall minimum)				
	SVR (%)	Cd	Sn	Zn	Cr	Cu	Mn	Ni	Depth (m)	Al (%)	Fe (%)	Hg	Pb
OUTFALL	15.3	1.30	14.4	120	39.0	43.1	350	23.5	69	2.27	2.54	.18	24.0
NEAR-OUTFALL	11.5	.74	13.8	105	42.8	48.5	373	24.2	101	2.71	2.99	.19	30.6
REFERENCE	10.3	.48	5.7	81	35.2	35.7	288	21.0	181	2.96	3.35	.20	36.3

TABLE 11 FIELD AND LAB REPLICATED SEDIMENT SAMPLES COLLECTED 10 APR 86

		METALS (ug/g)													
Station #	Depth (m)	Al (%)	Cd	Cr	Cu	Fe (%)	Hg	Mg (%)	Mn	Mo	Ni	Pb	Sn	Zn	SVR (%)
FIELD REPLICATES															
9.10	98	3.02	.7	52.0	57.4	3.27	.19	1.29	386	7.9	29	38	9	121	11.9
9.20		3.06	.3	33.9	36.2	3.35	.17	1.31	267	21.3	22	41	4	87	11.7
9.30		2.96	1.5	59.5	68	3.18	.17	1.27	423	.8	31	33	11	133	11.7
MAX		3.06	1.5	59.5	68	3.35	.19	1.31	423	21.3	31	41	11	133	11.9
MEAN		**3.01**	**.8**	**48.5**	**53.9**	**3.27**	**.17**	**1.29**	**359**	10	**27.3**	**37.33**	**8**	**114**	**11.8**
STD		.05	.61	13.16	16.19	.09	.01	.02	81.51	10.41	4.73	4.04	3.61	24.08	.12
CV(%)		2	73	27	30	3	8	2	23	104	17	11	45	21	1
LAB REPLICATES															
4.11	43	1.76	1.5	40.6	54.7	2.21	.21	.91	375	18.7	27	16	4	120	31.3
4.12		1.70	1.6	37.2	48.7	2.14	.14	.88	356	18.6	24	17	8	111	-
4.13		1.74	1.1	29.8	37.5	2.20	.14	.89	304	20.6	21	16	2	89	-
4.14		1.74	1.2	30.9	37.9	2.23	.13	.90	308	22.5	23	18	2	89	-
4.15		1.66	1.2	35.0	47.2	2.13	.20	.87	355	19.2	25	18	6	108	-
MAX		1.76	1.6	40.6	54.7	2.23	.21	.91	375	22.5	27	18	8	120	-
MEAN		**1.72**	**1.3**	**34.7**	**45.2**	**2.18**	**.16**	**.89**	**340**	**19.9**	**24**	17	**4.40**	**103**	-
STD		.04	.22	4.46	7.40	.04	.04	.02	31.72	1.65	2.24	1	2.61	13.87	-
CV(%)		2	14	11	14	2	18	2	8	9	8	6	65	12	-
LAB REPLICATES															
13.11	82	2.49	1.0	41.4	42.7	2.76	.09	1.02	370	.8	24	22	15	103	9.64
13.12		2.55	.3	34.1	34.5	2.84	.12	1.04	316	9.1	23	22	10	88	-
13.13		2.52	1.3	41.7	42.9	2.75	.11	1.02	376	3.7	26	27	17	114	-
13.14		2.46	1.5	43	45.2	2.67	.11	.99	386	.8	25	23	20	104	-
13.15		2.50	1.6	47.6	49.4	2.78	.12	1.02	411	.8	29	18	19	112	-
MAX		2.55	1.6	47.6	49.4	2.84	.12	1.04	411	9.1	29	27	20	114	-
MEAN		**2.51**	**1.2**	**41.6**	**43**	**2.76**	**.12**	**1.02**	**372**	**3.6**	**26**	**23**	17	**105**	-
STD		.04	.14	3.08	3.23	.07	.00	.02	17.80	3.91	2.06	4.27	1.41	4.76	-
CV(%)		2	12	7	8	3	2	2	5	109	8	19	9	5	-

(Figure 3). Fibre depth and volatile fraction is dynamic and fluctuates from year to year (Tables 12 & 13). A three sampling period running-average was used to evaluate trends of increasing or decreasing volatile residues at each station. Thirteen B.C.F.P. stations (Figure 4) exhibited an increase, while 17 stations showed decreasing levels of SVR (Table 12). No trends were at five sites. Most of the increases were at sites S.E. of the outfall or at some of the centre-line stations of the grid (Figure 5), while declining values were N.W. of the outfall or on the edge of the sampling grid . Maximum values tended to be at stations nearest the outfall. Stations with a volatile fraction greater than 12% can be expected to have reduced benthic invertebrate populations (Tetra Tech 1986). Fifty percent of the 30 core stations sampled in 1986 could be so affected.

EPS studies in 1981, indicated that sediment volatile residue was highest at near the outfall (station 4). Between 1983 and 1986 sediment volatile residue increased at stations 4 and 6, declined at station 1 and 3, while no large changes were noted elsewhere. Unfortunately, the high SVR levels at the outfall indicate the continuance of a degraded benthic habitat. Of further note is the apparent decline in the sediment quality at station 3, which had "natural brown sediments" in November 1981 (Sullivan 1982), but were reducing in 1983 and 1986. A similar decline in sediment quality to reducing sediments is also evident at station 6.

In April 1986 sediments were finer, particularly at stations 5, 6, 10 where very fine sands were obtained in contrast to the coarse sand and granules collected in November 1983. Sediments collected in November 1983 may have been sorted by autumn storms. Alternatively, this change in sediment particle size may reflect a sampling bias, not an actual change in sediment composition. Two potential sources of bias exist: the actual sample obtained by the grab, and/or the subsample taken from the grab for lab submission.

When the sediment metals sampled in 1981 (Sullivan 1982) are compared with 1983 and 1986 (Appendix V) the following patterns emerge in each of the outfall, near-outfall and reference locations:

PATTERN	ELEMENT	LOCATION OF MAXIMUM VALUES
declining values:	Cd, Zn, Cu	outfall, outfall, near-outfall
rising values:	Pb	reference area, near-outfall
rising values:	Hg	reference area

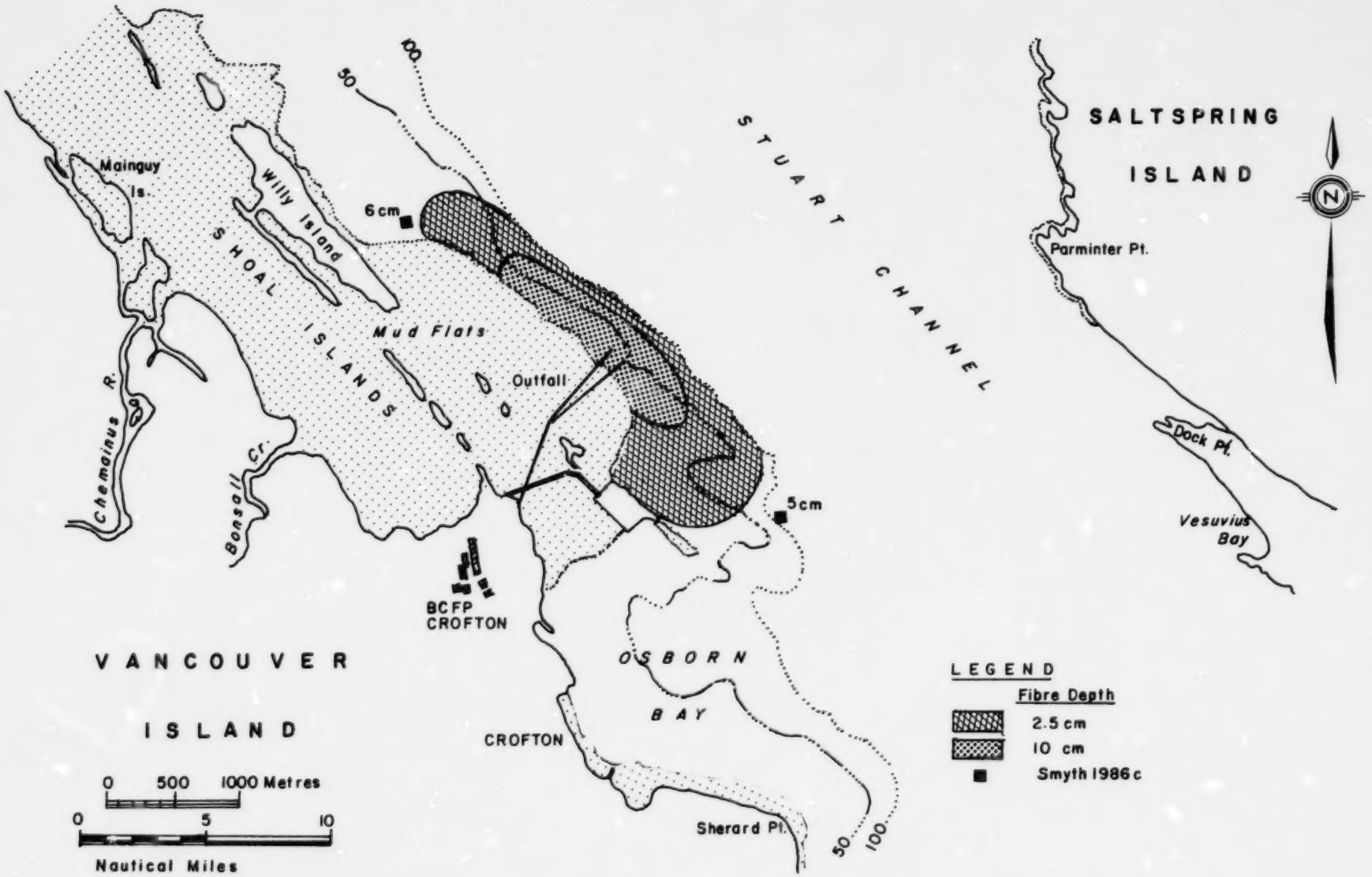

FIGURE 3 FIBRE DEPOSITION AROUND BCFP CROFTON OUTFALLS (From Ellis and Jones 1975)

TABLE 12 BCFP CORE DATA SHOWING SEDIMENT VOLATILE RESIDUE FRACTION 1975-86 (SMYTH 1986c).

STATION	JUNE 75	APRIL 78	NOV 79	NOV 80	AUG 1983	AUG 86	TREND
A1	-	-	.119	.183	.359	-	I
A2	.137	.074	.105	.154	.153	.089	I
A3	-	.125	.141	.129	.147	.139	I
A4	.210	.181	.134	.133	.149	.120	D
A5	.207	.140	.148	.129	.122	.115	D
A6	.165	.142	.132	.125	.122	.134	D
A7	.160	.427	-	-	-	-	-
A8	.168	.126	-	-	-	-	-
B1	.673	.385	.524	.704	.894	.770	I
B2	.379	.370	.386	.315	.201	.247	D
B3	.156	.185	.116	.165	.134	.119	D
B4	.151	.191	.153	.172	.160	.161	NT
B5	.193	.153	.155	.149	.098	.111	D
B6	.176	.143	.147	.122	.144	.133	D
C1.5	-	.128	.095	.091	.095	.067	D
C2	.134	.079	.092	.122	.074	.067	D
C2.5	-	-	.123	.098	.096	.114	D
C3	.146	-	-	-	.124	.066	D
C4	.147	.154	.155	.163	.143	.145	NT
C5	.193	.150	.133	.139	.144	.126	D
C6	-	-	-	.141	.144	.120	D
D1	.799	-	.578	.456	-	.909	I
D1.5	-	.408	.408	.261	.417	.566	I
D2	.697	.263	.231	.154	.204	.177	D
D3	.290	.244	.246	.118	.141	.106	D
D4	.197	.074	.039	.134	.145	.125	I
D5	.066	-	-	-	.127	.115	I
E1	.550	.695	.605	.751	.449	.523	
E2	.190	.380	.257	.204	.221	.115	D
E3	.208	.145	.163	-	.170	.110	D
E4	.124	.166	.120	.141	.142	.126	NT
E5	.107	.128	.104	.139	.139	.136	I
E6	-	-	-	.051	-	.113	I
F0	.028	.077	-	.040	.025	-	D
F0.5	-	.025	.038	.024	.095	-	I
F1	.042	.073	-	.037	.042	-	NT
F2	.042	.167	-	.025	.020	-	D
F3	.025	.068	-	.026	.027	-	NT
F4	.026	-	-	.029	.040	-	I
G0.5	-	.309	-	.054	.072	-	NT
G1	.040	.056	.070	.026	.043	-	D
G2	.022	.040	-	.030	.042	-	I

Trend analysis by 3 period running average (Appendix VIII).

	N
D= DECREASE IN SVR	21
I= INCREASE IN SVR	14
N= NO TREND IN SVR	5

TABLE 13 BCFP CORE DATA SHOWING FIBRE ACCUMULATION (CM), 1975 TO 1986 (SMYTH 1986c)

STATION	JUNE 75	APRIL 78	NOV 79	NOV 80	AUG 83	AUG 86
A1	NC*	NC	5	3.5	>3	No core
A2	-*	3.6	+	2	13.5	*
A3	-*	+	-	-	13.5	*
A4	8.5	-	-	-	-	+
A5	+	-	-	-	-	+
A6	+	-	-	-	-	*
A7	+	-	NC	NC	NC	NC
A8	+	-	NC	NC	NC	NC
B1	23	17.0	17	30	>12.3	8
B2	>9.0	16.4	19	23	<21	6
B3	10	9.7	11	11	14	12
B4	8	6.7	7	5	7	*
B5	10	6.7	+	2	3	*
B6	9.5	+	+	+	+	*
C1.5	NC	3.6	4	1.5	2	4
C2	7.5	4.3	+	3	9	6
C2.5	NC	NC	+	3	14	*
C3	8.5	NC	NC	NC	>11	3
C4	8.5	+	-	-	4	+
C5	6.5	+	-	-	-	*
C6	NC	NC	NC	-	-	*
D1	7	NC	-16.5	NC	NC	*
D1.5	NC	15.2	14	21	>16.7	*
D2	15.5	16.4	13	13	13	7
D3	10.5	14.8	10	11	11	10
D4	14	+	+	2	10	5
D5	9.5	NC	NC	-	9	*
E1	29	>23.7	>15.5	13	>16	>7
E2	10	10.9	11	12	14	10
E3	6.5	9.1	10	NC	18	7
E4	8.0	7.3	5	4	13	5
E5	13.5	+	+	+	+	*
E6	NC	NC	NC	+	-	*
F0	23	13.5	NC	1	23	NC
F0.5	NC	9.5	+	1	14	NC
F1	14	6.0	NC	8	17.5	NC
F2	+	4.5	NC	-	9	NC
F3	+	4.0	NC	+	+	NC
F4	+	NC	-	-	-	NC
G0.5	NC	13.0	NC	7	>23	NC
G1	14	4	5	6	23	NC
G2	7	+	NC	+	+	NC

NC = No Core
+ = Fibre Present
- = No Discernible Fibre
* = Fibres Visible in Photos

FIGURE 4 BCFP CORE STATION LOCATIONS, 1975-1986
(From Sercombe 1984)

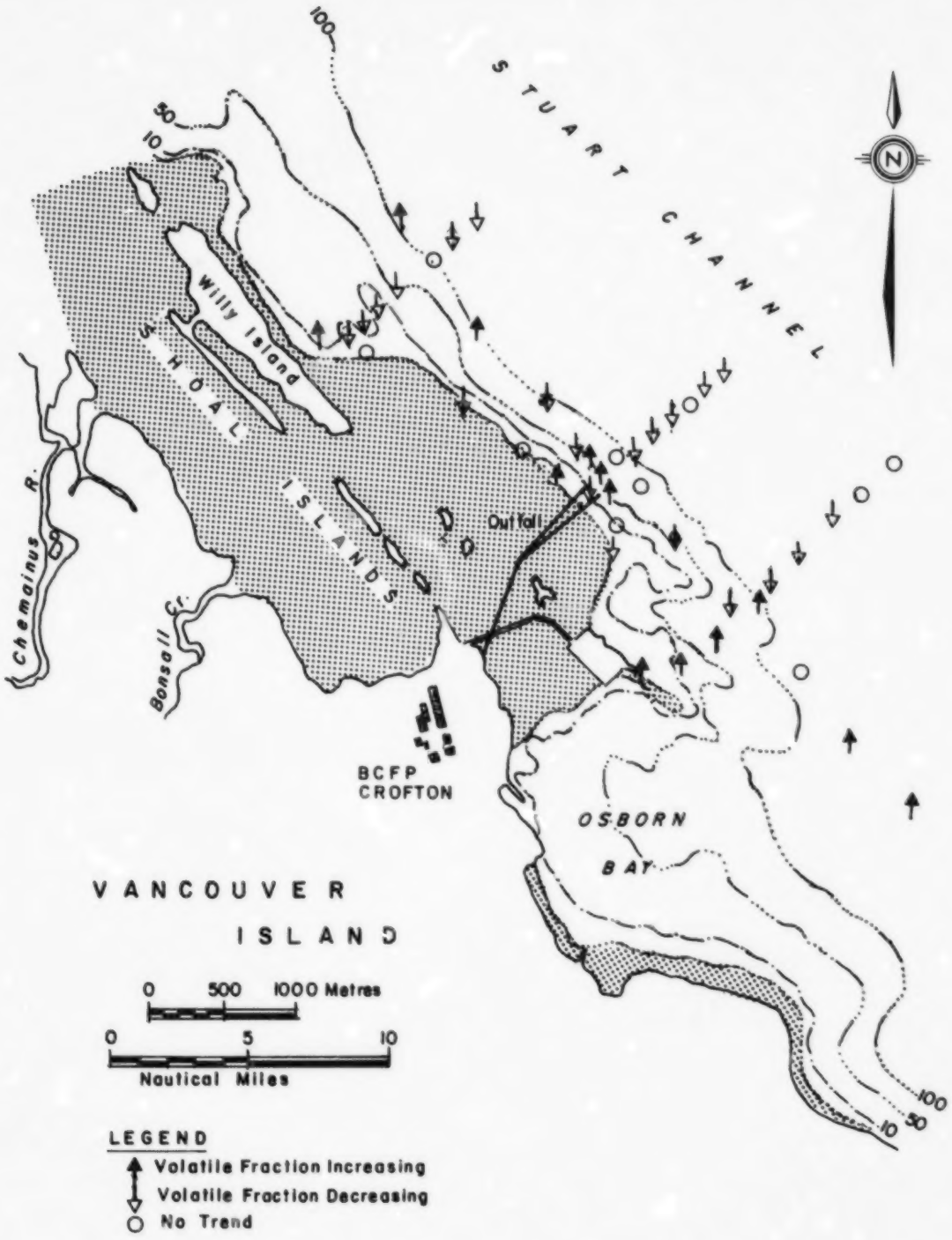

FIGURE 5 BCFP CORE STATION LOCATIONS, 1975-1986 INDICATING CHANGES IN VOLATILE FRACTION (From Smyth 1986c)

Declining values for cadmium, copper, and zinc are evident at the outfall, and near outfall areas. Lead and mercury maxima were at the reference areas. Lead and mercury concentrations have risen at all stations and may thus indicate an analytical artifact due to changes in laboratory methods, or a "real" environmental change that is wide-spread. The new micro-wave digestion technique is 14 to 30% more efficient at determining the lead concentration of sediments than the old "hot block" method used prior to 1986 (Millward in prep.). In addition, the quality control data (Appendix VI) show that lead recovery ranged from 99-184% of the standard certified values. Thus, it is likely that the increase in lead levels noted are due to the change in lab technique.

Even though the increase in lead levels are quite large, the lead levels sampled (17-38 ug/g) are still low, given that the lead content of open sea sediments range from 8.4 to 60 ug/g (Nriagu 1978). The maximum lead level sampled (38 ug/g) is far below the level (300 ug/g) which would always impair benthic infaunal populations (Tetra Tech 1986).

3.4.3 **Biota.** Biota has not been extensively sampled by EP in this area since 1979 (Sullivan 1980). Limited oyster samples were collected by Nelson and Brothers (1986 unpublished data). Their data showed a decline in whole oyster zinc levels when compared to the same station sampled in 1979 by Goyette (unpublished data):

Whole Oyster Zn (ug/g dry wt.)		Location: 48 51.86N 123 37.99W
1979	12,800	(Goyette, unpubl. data)
1986	3,413	(Nelson and Brothers, unpubl. data)

Although zinc levels are still elevated, this is likely due to the slag body from the abandoned copper smelter, and not the B.C.F.P. mill. Zinc levels in the slag were 3.25% in 1977 (Goyette pers. comm.). Ellis et al. 1981 also investigated the recovery of zinc levels in oysters in the Crofton area and found a decrease from 14,000 (ug/g dry wt.) in 1973 to 570 (ug/g dry wt.) in 1979.

A recent analysis of oysters collected in June 1983 (Imber et al. 1987) found that oysters collected near the outfall had elevated zinc and copper levels:

Oyster (digestive gland)	Zinc	Copper
	(ug/g dry wt.)	
Crofton outfall	1058	72.8
Sherard Point	752	75.2
Norway Island	541	34.6
Yellow Point	1821	50.4

However, Imber et al. 1987 also noted that zinc was inexplicably high at Yellow Point.

Sampling should be undertaken to establish present oyster metal levels in areas previously sampled by Nelson and Goyette (1973) and Ellis et al. 1981. To this end BCMOEP has recently collected oysters in the vicinity of the mill (L. Erickson, pers. comm.)

Groundfish tissue trace metal levels sampled by Nelson and Brothers in April 1986 are listed in Appendix VII. Selected metal levels in English Sole (Parophrys vetulus) are listed below:

REFERENCE	Sample Year	n	(ug/g dry wt.) Cd	Cr	Cu	Hg	Ni	Pb	Zn
*Sullivan 1981	1979	2	ND	ND	10.6	.31	ND	.6	21.6
*Nelson and Brothers (unpublished)	1986	1	ND	#.6	1.4	.08	ND	ND	33

ND = not detectable

\# = detection limit lowered

Such small samples sizes make interpretation difficult, but copper and mercury levels may have decreased, while zinc appears to be slightly higher. All the above 1986 levels are below the Canadian Guidelines for metals in fish products (DFO 1983).

4 FUTURE MONITORING REQUIREMENTS

4.1 Water Quality

The present report indicates that the main impact of the mill is to benthic habitat. Water quality, in terms of dissolved oxygen was not a significant problem, except at outfall station (1) during Nov 83, where DO at 40 m was 49% saturation (4.37 mg/L). Water quality monitoring should be done in November because the previously documented dissolved oxygen depressions were most pronounced at this time period. Future dissolved oxygen monitoring by EP should include as a minimum, sampling at outfall station (1) and at reference stations 8 and 9. Depths sampled in 1986 should be repeated and tri-stimulus colour samples should be taken in order to determine relative effluent concentration and trapping in the water column. A grab sample of effluent from the discharge pipe should also be taken and analysed for colour. This would allow for a more accurate determination of mill effluent dilution in receiving waters. The effluent sample should also be analysed for chlorophenols and resin acids, (toxic organic contaminants which have been detected in pulp mill effluents).

The non-filterable volatile residue (NFR) (fibre) loading of the mill can be determined from mill monitoring data, hence it need not be monitored in the waters.

Near-bottom water quality over the fibre mat should be also be assessed (perhaps by SCUBA divers - collected samples) and compared to a reference area to determine if the fibre mat is influencing the water concentrations of nutrients (ammonia and phosphate; Pearson, 1980) and/or organic contaminants.

Mill water quality monitoring data (Smyth 1986 a, b) also indicated the limited impact of the effluent on the water quality of Stuart Channel. Their data analysis should in future use only stations 8 and 9 as reference sites to compare with outfall locations since station 7 is often contaminated with effluent.

4.2 Sediment Quality.

The prime problem with the benthic habitat in the vicinity of the outfall is the accumulation of pulp fibres which forms reducing sediments and a bacterial mat, with the consequent reduction in benthic species diversity and abundance. The high sediment volatile residues

serve as an objective indicator of the spatial extent of the organic woody deposits. Due to the low variability within field replicates, single grab samples are adequate to determine volatile residue content at each station. Further PISCES IV submarine observations should be conducted to visually map the present extent of the fibre bed, and to document the concurrent changes in epibenthic species and water quality.

Although sediment metals did not exhibit a large increase except for lead, triplicate sediment sampling should be conducted once every 3 years at 1986 locations. Analysis for cadmium, copper, and lead should all be done using the more accurate Jarrel Ash (AAS) with the graphite furnace, instead of the ICAP. Zinc and mercury monitoring should also continue.

B.C.F.P. Crofton should annually repeat their grid of 30 sediment stations (Smyth 1986c) in Stuart Channel to accurately assess the change in fibre bed size which may be occurring. Sediment should be visually described in terms of being reducing or oxidizing, and the sediment sulphide levels should be measured. The cores should be sectioned to produce data on the vertical extent of high volatile sediment fractions. This would produce more quantitative data than the "fibre thickness" measurement currently employed. The high quality colour photographs of the cores should be continued as they clearly indicate when fibres are present.

4.3 Biota

Although the shellfish areas in the vicinity of Shoal Island are closed, it would be useful to know the change in metal levels in oysters since they were last sampled by Nelson and Goyette (1973). Similarly, trawls in Osborn Bay (CR3) and Stuart Channel (CR2, ST2) should be re-examined for changes in tissue metal levels.

B.C.F.P. Crofton should repeat their previous oyster sampling program in addition to doing an annual intertidal assessment of the impact of their foreshore discharge as requested of other coastal pulpmills as part of their provincial Waste Management permits. Consideration should also be given to conducted sediment bioassays using Macoma sp. or Rheopoxinius. BCMOEP recently found sediments at Powell River to be toxic to Macoma (B. Moore, pers. comm.).

4.4 Dioxins and Chlorinated Organic Compounds

4.4.1 Dioxins. A recent USEPA study (Amendola et al. 1987) indicated that kraft mill chlorine-bleach plants were a source of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD) and polychlorinated dibenzofurans (PCDF). In a national U.S.A. survey, fish downstream of mills were found to be contaminated with up to 85 parts per trillion 2378-TCDD (USEPA 1987).

In Sweden, marine sediments sampled had a gradient of dioxin related to an east coast mill (Iggesund Mill: 270 kt/year):

Distance from Mill (km)	TCDF parts per trillion (pg/g)	TCDD
4	360	64
9	160	66
16	120	27
29	79	21
Background Sediment 30-35 cm deep	4.4	6.8
South Bothnia Seawater	87	19

pers. comm. source: A Melin, Swedish Environmental Protection Board, Box 1302, S-171 25, Solna, Sweden.

In another study, crabs sampled had elevated levels of dioxins in their hepatopancreas (Fallenius, U-B, 1987).

The Canadian Wildlife Service (CWS) has sampled great blue heron eggs at Crofton since 1983 and found them to contain the highest level of dioxins compared to other locations in B.C. and Quebec. Co-incident with these high dioxin levels has been a failure of the Crofton colony to produce viable chicks. Levels of dioxins found in eggs at Crofton were at concentrations known to cause "chick edema disease" which is fatal to domestic chicken embryos, however direct inter-species toxicity comparisons cannot be readily made. Interpretation of the levels of dioxins from the 1987 sampling of heron and comorrant eggs will be published as they become available (Phil Whitehead, pers. comm.).

These studies indicate the need to obtain dioxin data from B.C. marine ecosystems which receive chlorine bleach plant effluent and other potential sources of dioxin such as the wood-protection industry. EP (Pacific and Yukon Region) collected sediment, water and tissue

(molluscs, crabs, fish) samples for dioxin analysis, from various pulpmill and wood treatment facilities near Crofton, Port Alberni, Victoria and the lower Fraser River (Chris Garrett, pers. comm). Future sampling is planned at other mill locations including Powell River. Results of this dioxin investigation will be reported as they become available.

4.4.2 Extractable Organic Chlorine Compounds(EOCL).

Researchers in Sweden have studied the link between chlorinated bleach-plant effluents and the concentrations of ether extractable organic chlorine (EOCL) compounds. They have also documented the biological effects of these chlorinated organic compounds (Sodergren, A. et al. 1987) using model ecosystem experiments and field sampling (Annergren et al. 1985?).

The extractable organic chlorine (EOCL) concentrations were determined by neutron activation analysis (NAA) and served as an indicator for exposure to mill effluents. More than 90% of the 3,4,5-triochloroguaiacol, catechols, chlorinated phenols, were identified. Toxaphene, PCB and DOTs, although not linked to mill effluents were also identified.

There was a clear linkage between the benthic sediment dynamics (erosional or depositional) and the concentrations of EOCL found. Within 2 km of the discharge, the bottom sediments were covered with fibres and had high levels (1100 ug/g) of EOCL compounds. The identified fraction (chlorinated phenols, guaiacols, catechols and PCB) constituted only minor portion (<1%) of the EOCL content of the sediment. Another study showed that dioxin and furan concentrations were correlated with EOCL levels. The isomeric distributions of chlorinated dioxins and dibenzofurans indicated that "the pulpmill effluent contributes significantly to the xenobiotic content of the sediments, taken 29 km from the outlet" (Sodergren, A. et al. 1987).

EOCL concentrations in fish and gastropod tissues decreased along a gradient from the chlorine-bleached kraft mill outfall, and decreased in magnitude in conjunction with lowered chlorine consumption at the mill. Biological effects in fish, associated with the increased EOCL concentrations included:

- impaired liver function
- impaired immune defence
- impaired ion balance
- impaired reproduction

Increased parasitism and fin erosion in fish within 10 km of the outfall was also noted. Fish with pelagic larval stages (herring) had decreased recruitment within 8 km of the outfall. Contaminated sediments hampered the reproduction and survival of the clam Macoma baltica, and micro-crustaceans like harpacticoids and ostrascods (Sodergen, A. et al. 1987).

Model ecosystem studies using the brown alga Fucus vesiculosus with adherent fauna, three-spined sticklebacks, and small flounders (Platichtys flesus) were supplied with flow through bleached-kraft mill effluent concentrations equivalent to dilution of 400 and 2000:1. The table below summarizes the results:

Dilution	Effects
1.166	lowest fry survival, increased parasitism of fish, decreased invertebrate abundance
1:330	low fry survival, parasitism high
1:1140	altered fry survival and parasitism rates
1:5910	effects still exist at low levels

The addition of oxygen bleaching or aeration lagoons reduced the area affected from >5000:1 to about 2000:1 dilution by reducing the amount of organically bound chlorine discharged.

4.4.3 Monitoring Needs. The "zone of influence" of EOCL (including TCDD & TCDFs) contamination is dependant upon the sediment dynamics and current regime of the receiving environment. The widespread (up to 29 km) contamination found in Swedish coastal waters should encourage EP (Pacific and Yukon) to define the zones of influence around the coastal mills. Sampling should be a two-staged effort:

1. Widespread EOCL/TOCL broad-spectrum (effluent, sediment, water, algae, invertebrates, fish tissues) sampling to roughly define the zones and ecological compartments of organic chlorine contamination, coupled with dioxin narrow-spectrum (sediments, resource species) sampling at "worst case" initial dilution areas should be undertaken near one or two mills, including Crofton.

2. After the intial zone and compartments of organic contamination have been outlined, more detailed resolution near the other mills can proceed more efficiently.

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APPENDIX I

CROFTON STUART CHANNEL
STATION LOCATIONS
22 NOV 83

APPENDIX I CROFTON STUART CHANNEL STATION LOCATIONS 22 NOV 83

Station	Latitude	Longitude
1	48 53.55 N	123 38.03 W
2	48 53.48 N	123 37.93 W
3	48 53.58 N	123 37.96 W
4	48 53.62 N	123 38.06 W
5	48 53.07 N	123 37.05 W
6	48 53.99 N	123 38.42 W
8	48 55.55 N	123 36.43 W
10	48 53.93 N	123 37.05 W

APPENDIX II

CROFTON STUART CHANNEL
STATION LOCATIONS
10 APR 86

APPENDIX II CROFTON STUART CHANNEL STATION LOCATIONS 10 APR 86

Station	Latitude	Longitude
1	48 53.56 N	123 38.01 W
2	48 53.47 N	123 37.87 W
3	48 53.61 N	123 37.88 W
4	48 53.62 N	123 38.06 W
5	48 53.19 N	123 37.18 W
6	48 53.99 N	123 38.42 W
9 benthic	48 56.45 N	123 41.26 W
9 water	48 56.46 N	123 41.23 W
11	48 54.29 N	123 39.11 W
12	48 53.8 N	123 38.32 W
13	48 53.25 N	123 37.45 W

APPENDIX III

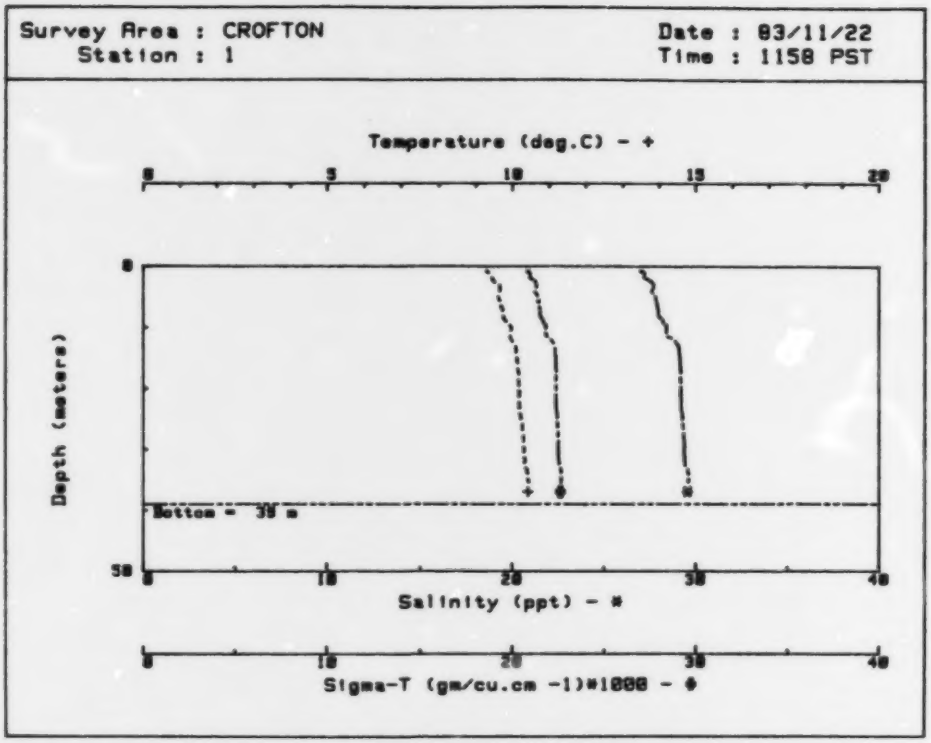
CTD PROFILES AT CROFTON - NOVEMBER 22, 1983

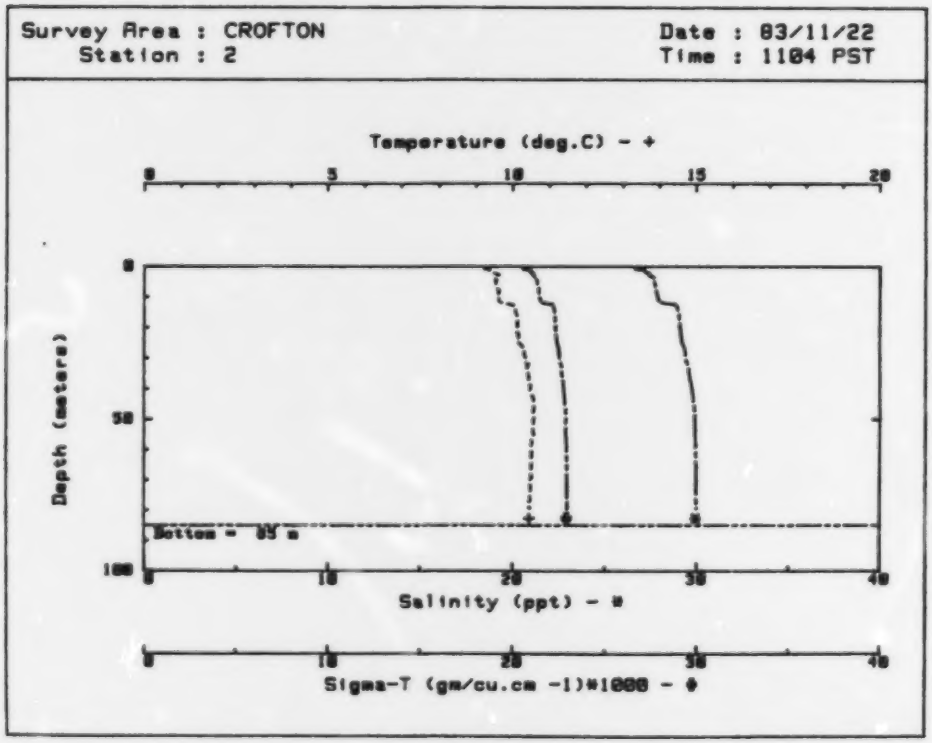
a) STATION 1 & 2

b) STATION 3 & 4

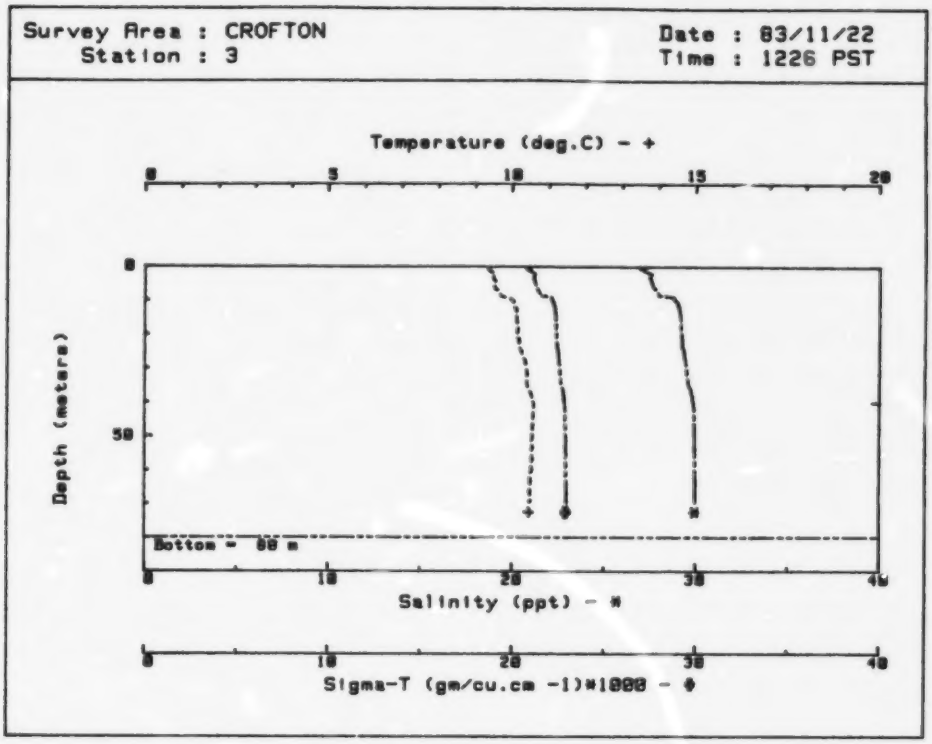
c) STATION 5 & 6

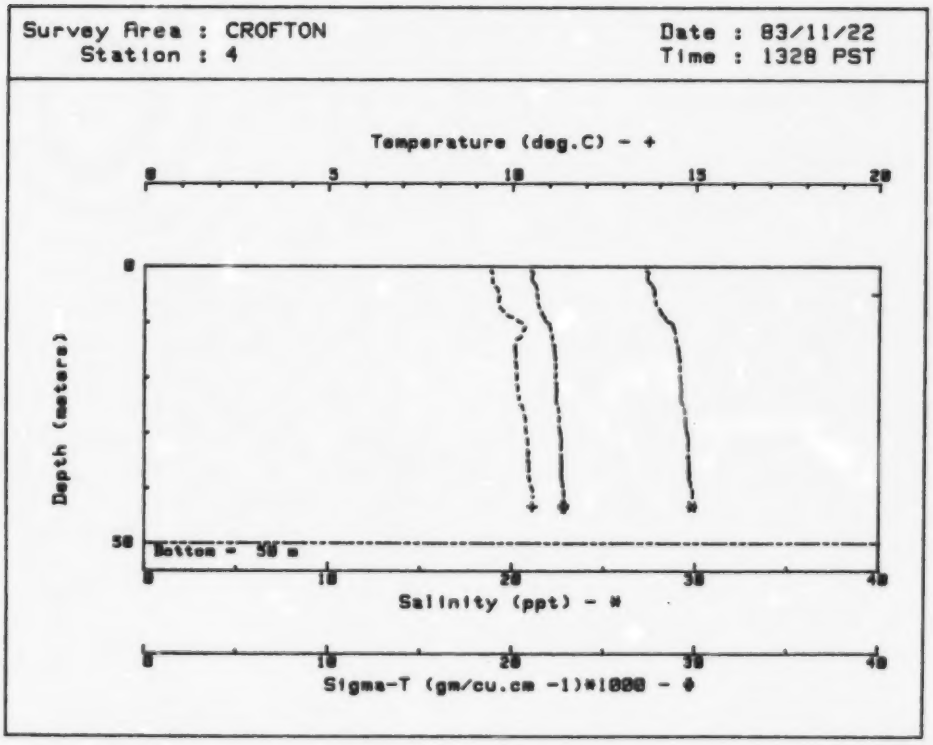
d) STATION 8 & 10



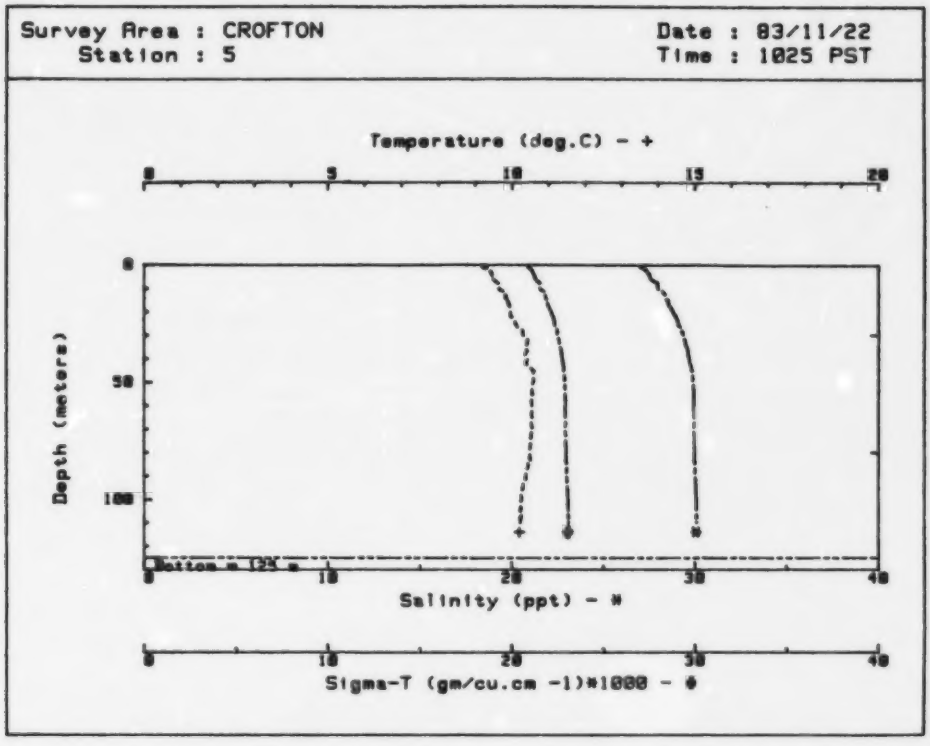


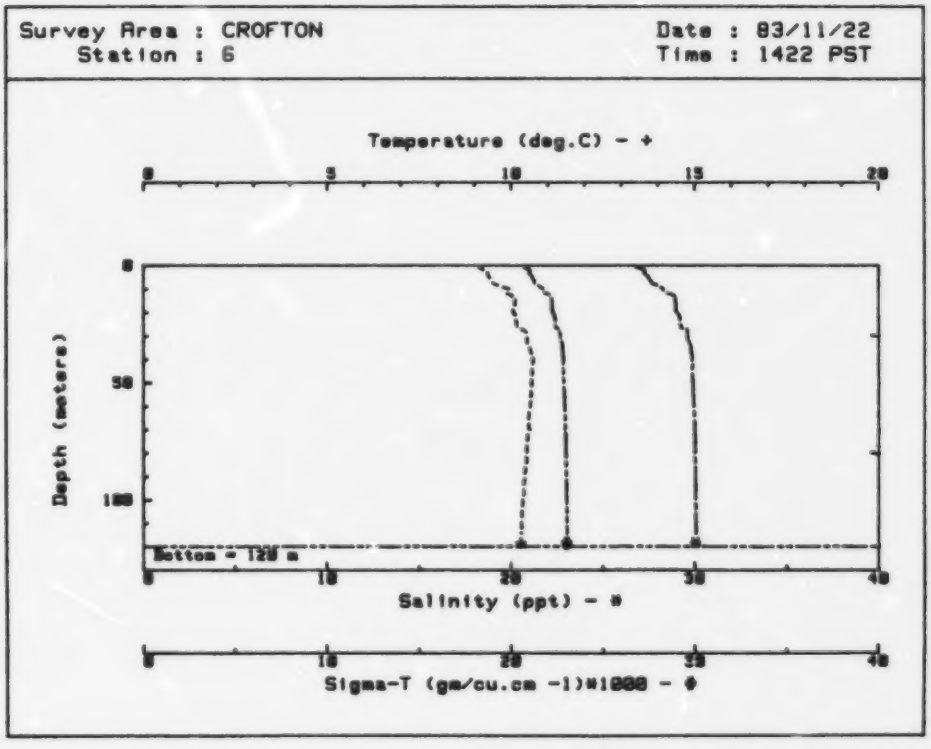
APPENDIX IIIa CTD PROFILES AT CROFTON - November 22, 1983



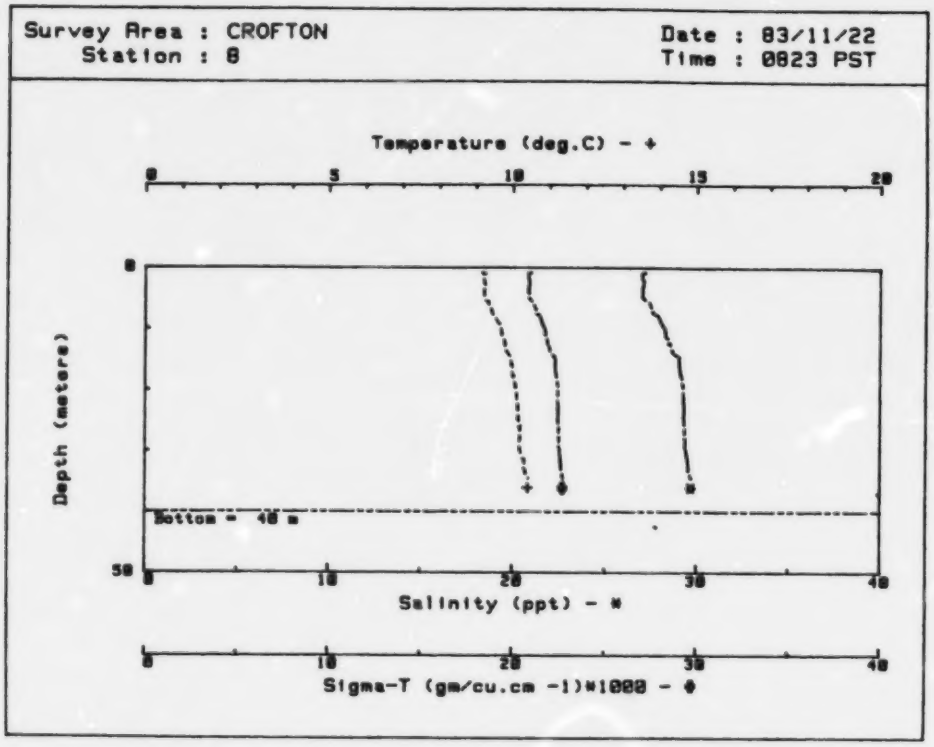


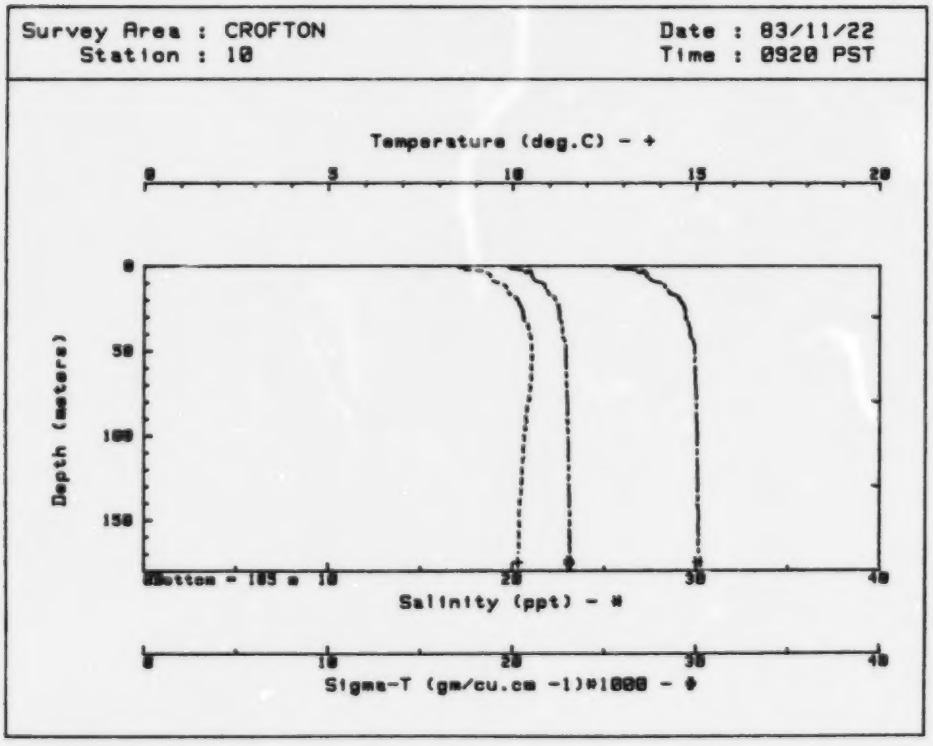
APPENDIX III b CTD PROFILES AT CROFTON - November 22, 1983





APPENDIX III c CTD PROFILES AT CROFTON - November 22, 1983

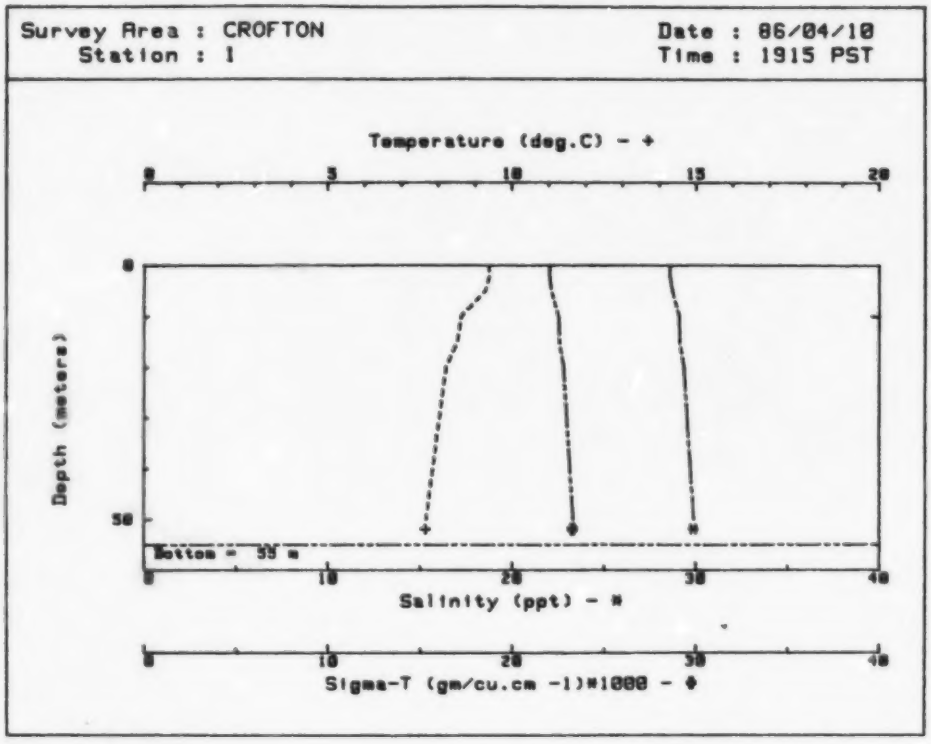


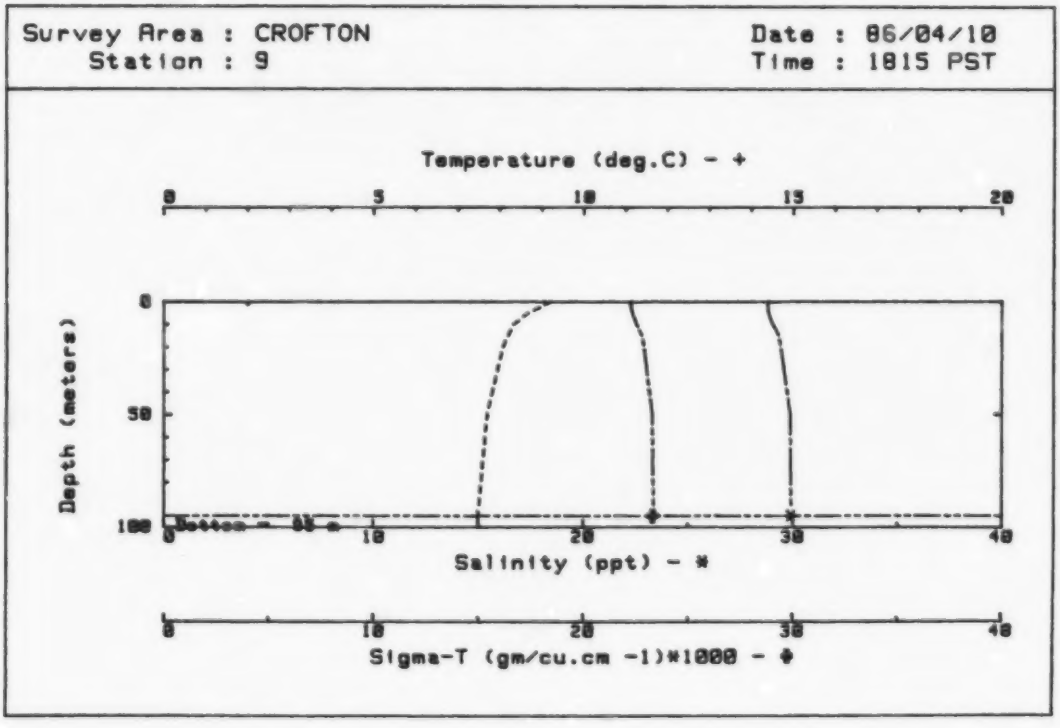


APPENDIX IIId CTD PROFILES AT CROFTON - November 22,1983

APPENDIX IV

CTD PROFILES AT CROFTON - APRIL 10, 1986
STATION 1 & 9





APPENDIX IV CTD PROFILES AT CROFTON - April 10, 1986

APPENDIX V

CHANGES IN SEDIMENT METAL CONTENT FROM NOVEMBER 1981, NOV 1983, APR 1986

APPENDIX V CHANGES IN SEDIMENT METAL CONTENT FROM NOV 1981, NOV 1983, APR 1986

Station #	Cd 1981	Cd 1983	Cd 1986	Cu 1981	Cu 1983	Cu 1986	Hg 1981	Hg 1986	Pb 1981	Pb 1983	Pb 1986	Zn 1981	Zn 1983	Zn 1986
OUTFALL STATIONS														
1	2.29	4.20	2	36	77.6	53.8	.13	.21	9	14	30	206	151	158
2	2.54	3.10	.90	49.3	76.5	29.9	.14	.14	12	14	21	178	176	107
3	1.41	2.80	1	55.2	64.8	43.3	.14	.20	19	11	28	154	169	111
4	3.46	3.10	1.30	66.7	80.5	45.2	.17	.16	15	11	17	192	195	103
MAX	3.46	4.20	2	66.7	80.5	53.8	.17	.21	19	14	30	206	195	158
MEAN	2.43	3.30	1.30	51.8	74.9	43.1	.14	.18	14	13	24	183	173	120
STD	.84	.62	.50	12.77	6.91	9.89	.02	.03	4	2	6	22	18	26
CV(%)	35	19	38	25	9	23	13	19	31	14	25	12	11	21
NEAR-OUTFALL STATIONS														
5	.71	1.20	.30	51.5	57	35.3	.21	.23	22	18	38	133	132	80
6	3.40	1.70	1.20	60.5	70.4	61.5	.17	.19	20	15	36	278	141	130
MAX	3.40	1.70	1.20	60.50	70.40	61.50	.21	.23	21.60	18	38	278	141	130
MEAN	2.06	1.45	.75	56	63.7	48.4	.19	.21	21	17	37	206	137	105
STD	1.90	.35	.64	6.36	9.48	18.53	.03	.03	1.34	2.12	1.41	102.53	6.36	35.50
CV(%)	93	24	86	11	15	38	15	13	7	13	4	50	5	34
REFERENCE STATIONS														
8	.60	.70		19.9	43.1		.14		12	9		74	94	
10	.70	.70	.30	42.9	48.2	35	.17	.18	19	17	35	102	115	83
9			.83			53.9		.17			37			114
7			.30			18.2		.26			37			48
MAX	.70	.70	.83	42.90	48.20	53.90	.17	.26	19	17	37	102	115	113.5
MEAN	.65	.70	.48	31.4	45.7	35.7	.16	.20	16	13	36	88	105	81
STD	.07	0	.31	16.26	3.61	17.86	.02	.05	5.30	5.66	1.15	19.66	14.85	33.02
CV(%)	11	0	64	52	8	50	15	24	34	44	3	22	14	41

APPENDIX V OSBORNE BAY GROUNDFISH TISSUE METAL LEVELS (UG/G DRY WT.) APRIL 1986
(NELSON AND BROTHERS UNPUBL. DATA.)

FISH	Al	As	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Sn	Zn
CO SOLE	<4	168	<2	1	.8	20.20	.310	1360	.69	<.4	<2	<2	4.50	23
FLAT HEAD SOLE	5	25	<2	.60	.60	28.10	.260	1480	1.33	<.4	<2	<2	39.20	27.50
ENGLISH SOLE	7	191	<2	.60	1.40	34.90	.080	1290	.67	<.4	<2	<2	24.40	33
SAND DAB	10	77	<2	.80	.70	45.40	.130	1220	1.01	<.4	<2	<2	62.10	22.70
MEAN	6	128	<2	.73	.93	27.73	.217	1376.67	.90	<.4	<2	<2	23	28
STD	2.52	84.91		.12	.44	8.72	.093	134.54	.33				18.99	5.15
VAR	6.33	7209.33		.01	.19	75.96	.009	18100	.11				360.79	26.56
CV(%)	42	66		16	47	31	43	10	37				84	18

1979 DATA FROM SULLIVAN 1981

FISH	Al	As	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Sn	Zn
ENGLISH SOLE			<2	<2.63	17.6		.282				<3.73	.8		19
ENGLISH SOLE			<2	<0.7	3.5		.333				<3.89	.4		24
MEAN					10.6		.308					.6		21.6

APPENDIX VI

LAB PERFORMANCE DATA ON MARINE SEDIMENT STANDARDS

APPENDIX VI LAB PERFORMANCE DATA (UG/G DRY WT.)
MESS MARINE SEDIMENT STANDARD

	CERTIFIED		% RECOVERY		REPLICATE	STANDARDS REPLICATES							
ELEMENT	min.	max.	MIN.	MAX.	MEANS	S.E.	CV%	S.D.	1	2	3	4	5
Hg	.157	.185	130	153	.241	.005	4	.011	.231	.229	.255	.246	.242
Al (%)	5.60	6	34	37	2.06	.024	3	.055	2.1	2	2.1	2	2.1
As	10.60	10.60	0	0	.80	0	0	0	.8	.8	.8	.8	.8
Ba	270	270	19	19	51.18	2.315	10	5.177	56.5	55.8	44.5	51.5	47.6
Be	1.70	2.10	39	48	.82	.185	50	.413	1.1	.1	.9	1	1
Ca	4363	5277	50	60	2618	12.410	1	27.749	2620	2630	2640	2570	2630
Cd	.50	.70	57	80	.40	.032	18	.071	.4	.4	.3	.4	.5
Co	8.90	12.70	86	123	10.98	.978	20	2.188	13.5	12.8	9.3	8.4	10.9
Cr	60	82	38	52	31.28	1.678	12	3.751	36.3	32.3	26.6	32.5	28.7
Cu	21.30	28.90	79	107	22.82	1.706	17	3.815	27.3	23.6	18.1	25.3	19.8
Fe (%)	2.90	3.20	83	91	2.64	.024	2	.055	2.6	2.6	2.7	2.6	2.7
Mg (%)	.81	.92	77	87	.71	.005	2	.012	.706	.708	.710	.687	.720
Mn	488	539	74	82	400.60	15.075	8	33.709	445	405	353	412	388
Mo	2.20	2.20	178	178	3.92	1.691	96	3.780	.8	2	7.4	.8	8.6
Na (%)	1.70	2	35	41	.70	0	0	0	.7	.7	.7	.7	.7
Ni	26.80	32.20	63	75	20.20	1.158	13	2.588	23	21	16	20	21
P	576	698	103	125	717.80	2.557	1	5.718	719	719	720	708	723
Pb	27.90	40.10	99	143	39.80	1.241	7	2.775	38	44	37	41	39
Si (%)	30.70	32.50	0	0	.06	.012	46	.027	.10	.03	.06	.06	.04
Sn	6	6	90	90	5.40	.678	28	1.517	6	5	3	6	7
Sr	89	89	33	33	29.38	1.261	10	2.820	33.2	29.8	25.6	30.3	28
Ti	5262	5598	9	10	507	37.399	16	83.627	641	464	439	536	455
V	67.10	77.70	57	66	44.02	2.557	13	5.718	52	45.1	37	45.7	40.3
Zn	174	208	82	98	169.80	8.930	12	19.967	198	173	143	173	162

( )= indicates usual approximate value, obtained by NRC mass spectroscopy

APPENDIX VI (Continued)

	CERTIFIED		% RECOVERY		REPLICATES	STANDARDS REPLICATES							
ELEMENT	min.	max.	MIN.	MAX.	MEANS	S.E.	CV%	S.D.	1	2	3	4	5
Hg	.117	.141	120	145	.170	.003	4	.007	.162	.171	.165	.169	.181
Al (%)	6.04	6.48	39	42	2.54	.020	2	.045	2.61	2.51	2.51	2.56	2.51
As	9.7	12.5	0	0	8	0	0	0	8	8	8	8	8
Ba	330	330	16	16	52.16	3.448	15	7.709	64	52.7	47.2	43.7	53.2
Be	1	1.6	39	62	.62	.037	13	.084	.7	.7	.6	.5	.6
Ca	4901	5959	74	90	4414	42.261	2	94.499	4570	4350	4330	4400	4420
Cd	.21	.29	103	143	.30	0	0	0	.30	.30	.30	.30	.30
Co	9.3	13.5	50	73	6.76	1.543	51	3.450	9.9	8.2	8.3	1	6.4
Cr	109	137	33	41	44.90	4.044	20	9.043	60	46	42	36	41
Cu	15.8	21.2	55	74	11.68	1.465	28	3.276	17	12.3	10.7	8.5	9.9
Fe (%)	3.19	3.39	89	95	3.02	.034	2	.075	3.11	3.02	2.90	3.02	3.03
Mg (%)	1.31	1.63	78	97	1.27	.012	2	.027	1.31	1.25	1.24	1.27	1.27
Mn	214	244	78	89	191	13.936	16	31.161	242	194	178	159	182
Mo	1.5	1.5	731	731	10.96	3.200	65	7.155	.8	7.2	12	18.7	16.1
Na (%)	1.86	2.18	40	46	.86	.006	2	.013	.9	.9	.9	.9	.9
Ni	51.7	58.9	69	79	40.80	3.023	17	6.760	52	41	34	38	39
P	602	742	108	133	798.80	8.434	2	18.860	830	779	794	798	793
Pb	19.3	26.1	136	184	35.60	1.600	10	3.578	40	30	36	36	36
Si (%)	30.43	31.37	0	0	.04	.010	64	.023	.02	.07	.05	.02	.02
Sn	3	3	113	113	3.40	.678	45	1.517	5	2	5	2	3
Sr	96	96	30	30	28.96	2.216	17	4.956	36.7	30.6	26.2	23.9	27.4
Ti	4156	4544	4	5	190.40	24.887	29	55.649	238	242	210	134	128
V	88.5	98.3	46	51	44.96	4.340	22	9.704	60.1	47.6	42.2	34.7	39.7
Zn	107	131	72	88	94.04	9.023	21	20.177	129	90	79	91	81

( )= indicates usual approximate value, obtained by NRC mass spectroscopy

APPENDIX VII

OSBORNE BAY GROUNDFISH TISSUE METAL LEVELS

APPENDIX VII OSBORNE BAY GROUNDFISH TISSUE METAL LEVELS (ug/g dry wt.) APRIL 1986
(Nelson and Brothers unpubl. data.)

FISH	Al	As	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Sn	Zn
CO SOLE	<4	168	<2	1	.8	20.20	.310	1360	.69	<.4	<2	<2	4.50	23
FLAT HEAD SOLE	5	25	<2	.60	.60	28.10	.260	1480	1.33	<.4	<2	<2	39.20	27.50
ENGLISH SOLE	7	191	<2	.60	1.40	34.90	.080	1290	.67	<.4	<2	<2	24.40	33
SAND DAB	10	77	<2	.80	.70	45.40	.130	1220	1.01	<.4	<2	<2	62.10	22.70
MEAN	**6**	**128**	**<2**	**.73**	**.93**	**27.73**	**.217**	**1376.67**	**.90**	**<.4**	**<2**	**<2**	**23**	**28**
STD	2.52	84.91	-	.12	.44	8.72	.093	134.54	.33	-	-	-	18.99	5.15
VAR	6.33	7209.33	-	.01	.19	75.96	.009	18100	.11	-	-	-	360.79	26.56
C %	42	66	-	16	47	31	43	10	37	-	-	-	84	18

1979 DATA FROM SULLIVAN 1981

FISH	Al	As	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Sn	Zn
ENGLISH SOLE	-	-	<2	<2.63	17.6	-	.282	-	-	-	<3.73	.8	-	19
ENGLISH SOLE	-	-	<2	<0.7	3.5	-	.333	-	-	-	<3.89	.4	-	24
MEAN	**-**	**-**	**-**	**-**	**10.6**	**-**	**.308**	**-**	**-**	**-**	**-**	**.6**	**-**	**21.6**

APPENDIX VIII

TREND ANALYSIS ON BCFP CORE DATA:

Three Period Running Average on Volatile Function Data

APPENDIX VIII TREND ANALYSIS ON B.C.F.P. CORE DATA: THREE PERIOD RUNNING AVERAGE ON VOLATILE FRACTION DATA

STATION	JUNE 75	APRIL 76	NOV 79	NOV 80	AUG 1983	AUG 86	TREND *
A1	-	-	.119	.183	.359	-	
		.119	**.151**	**.220**	**.271**		I
A2	.137	.074	.105	.154	.153	.089	
		.105	**.111**	**.137**	**.132**		I
A3	-	.125	.141	.129	.147	.139	
		.133	**.132**	**.139**	**.138**		I
A4	.210	.181	.134	.133	.149	.120	
		.175	**.149**	**.139**	**.134**		D
A5	.207	.140	.148	.129	.122	.115	
		.165	**.139**	**.133**	**.122**		D
A6	.165	.142	.132	.125	.122	.134	
		.146	**.133**	**.126**	**.127**		D
A7	.160	.427	-	-	-	-	
							-
A8	.168	.126	-	-	-	-	
							-
B1	.673	.385	.524	.704	.894	.770	
		.527	**.538**	**.707**	**.789**		I
B2	.379	.370	.386	.315	.201	.247	
		.378	**.357**	**.301**	**.254**		D
B3	.156	.185	.116	.165	.134	.119	
		.152	**.155**	**.138**	**.139**		D
B4	.151	.191	.153	.172	.160	.161	
		.165	**.172**	**.162**	**.164**		NT
B5	.193	.153	.155	.149	.098	.111	
		.167	**.152**	**.134**	**.119**		D
B6	.176	.143	.147	.122	.144	.133	
		.155	**.137**	**.138**	**.133**		D
C1.5	-	.128	.095	.091	.095	.067	
		.112	**.105**	**.094**	**.084**		D
C2	.134	.079	.092	.122	.074	.067	
		.102	**.098**	**.096**	**.088**		
C2.5	-	-	.123	.098	.096	.114	
				.106	**.103**		D
C3	.146	-	-	-	.124	.066	
							D
C4	.147	.154	.155	.163	.143	.145	
		.152	**.157**	**.154**	**.150**		
C5	.193	.150	.133	.139	.144	.126	
		.159	**.141**	**.139**	**.136**		D
C6	-	-	-	.141	.144	.120	
							D
D1	.799	-	.578	.456	-	.909	
		.689	**.517**	**.517**	**.683**		I
D1.5	-	.408	.408	.261	.417	.566	
			.359	.362	.415		I
D2	.697	.263	.231	.154	.204	.177	
		.397	**.216**	**.196**	**.178**		D
D3	.290	.244	.246	.118	.141	.106	
		.260	**.203**	**.168**	**.122**		D
D4	.197	.074	.039	.134	.145	.125	
		.103	**.082**	**.106**	**.135**		I
D5	.066	-	-	-	.127	.115	

CONTINUED...

APPENDIX VIII (Continued)

STATION	JUNE 75	APRIL 76	NOV 79	NOV 80	AUG 1983	AUG 86	TREND *
E1	.550	.695	.605	.751	.449	.523	
		.617	.684	.602	.574		D
E2	.190	.380	.257	.204	.221	.115	
		.276	.280	.227	.180		D
E3	.208	.145	.163	-	.170	.110	
		.172	.154	.167	.140		D
E4	.124	.166	.120	.141	.142	.126	
		.137	.142	.134	.136		NT
E5	.107	.128	.104	.139	.139	.136	
		.113	.124	.127	.138		I
E6	-	-	-	.051	-	.113	
							-
F0	.028	.077	-	.040	.025	-	
		.053	.059	.033	.033		D
F 0.5	-	.025	.038	.024	.195	-	
		.032	.029	.086	.110		I
F1	.042	.073		.037	.042	-	
		.058	.055	.040	.040		NT
F2	.042	.167	-	.025	.020	-	
		.105	.096	.023	.023		D
F3	.025	.068	-	.026	.027	-	
		.047		.027			NT
F4	.026	-	-	.029	.040	-	
				.035			I
G 0.5	-	.309	-	.054	.072	-	D
			.182	.063			
G1	.040	.056	.070	.026	.043	-	D
		.055	.051	.046			
G2	.022	.040	-	.030	.042	-	I
		.031	.035	.036			I

* TREND ANALYSIS BY THREE PERIOD RUNNING AVERAGE